bart
impact
program

BART IMPACTS ON HIGHWAY TRAFFIC AND TRANSIT RIDERSHIP

technical memorandum

The BART Impact Program is a comprehensive, policy-oriented study and evaluation of the impacts of the San Francisco Bay Area's new rapid transit system (BART).

The program is being conducted by the Metropolitan Transportation Commission, a nine-county regional agency established by state law in 1970.

The program is financed by the U.S. Department of Transportation, the U.S. Department of Housing and Urban Development, and the California Department of Transportation. Management of the Federally-funded portion of the program is vested in the U.S. Department of Transportation.

The BART Impact Program covers the entire range of potential rapid transit impacts, including impacts on traffic flow, travel behavior, land use and urban development, the environment, the regional economy, social institutions and life styles, and public policy. The incidence of these impacts on population groups, local areas, and economic sectors will be measured and analyzed. The benefits of BART, and their distribution, will be weighed against the negative impacts and costs of the system in an objective evaluation of the contribution that the rapid transit investment makes toward meeting the needs and objectives of this metropolitan area and all of its people.

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BART IMPACT PROGRAM

BART IMPACTS ON HIGHWAY TRAFFIC AND TRANSIT RIDERSHIP

MAY 1977

TECHNICAL MEMORANDUM

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WASHINGTON, D.C.

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BART Impacts on Highway Traffic and Transit Ridership

Prepared by
Peat, Marwick, Mitchell & Co.

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16. Abstract

The 71-mile Bay Area Rapid Transit (BART) System, serving San Francisco, Oakland, Berkeley, and their suburbs, is the first regional-scale rapid transit system to open in the United States in over 50 years. This report is one of a series assessing the impacts of BART on transportation and travel in the Bay Area. The report documents what changes in aggregate highway traffic volumes, traffic congestion, bus ridership, and bus services have taken place in the four years since BART started service; and assesses the extent to which these changes may be attributable to BART.

Nearly half of BART's ridership has been diverted from bus services, but the loss of these trips has been largely offset by the use of bus to get to and from BART. The net BART-related loss of bus trips represents only 3% of total area-wide bus ridership. The prediction that BART would dramatically reduce automobile volumes and traffic congestion on the San Francisco-Oakland Bay Bridge has not been fulfilled. The net reduction in daily traffic attributable to BART amounts to less than 4% of the total, or between one and two years' normal growth. By increasing total transportation capacity in the heavily traveled corridor, BART's principal effect has been to allow previously suppressed trips to be made (by automobile and by BART) with the net result that total travel has increased substantially.

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The analyses reported here were undertaken by Peat, Marwick, Mitchell & Co. based on data compiled by a TSTB Project Team staffed by members of Peat, Marwick, Mitchell & Co., San Mateo, California; JHK & Associates, San Francisco, California; and Market Facts, Inc., Chicago, Illinois. Among the many organizations who provided data and assistance to the TSTB Project Team are:

- Alameda-Contra Costa Transit District
- Bay Area Rapid Transit District
- California Department of Transportation (Toll Bridge Administration and District 4)
- Golden Gate Bridge Highway and Transportation District
- Greyhound Lines
- Metropolitan Transportation Commission
- Public Utilities Commission, State of California
- San Francisco Municipal Railway
- University of California, Institute of Transportation Studies

The contributions of many individuals in these organizations are gratefully acknowledged. However, responsibility for the contents of the report rests with Peat, Marwick, Mitchell & Co.

*Transportation and Travel Impacts of BART: Interim Service Findings (TSTB Project Phase I Final Report), BART Impact Program Document No. FR 6-3-75, April 1976.

Metropolitan Transportation Commission

SAN FRANCISCO BAY REGION

CENTRAL AREA

BART: THE BAY AREA RAPID TRANSIT SYSTEM

Length: The 71-mile system includes 20 miles of subway, 24 miles on elevated structures and 27 miles at ground level. The subway sections are in San Francisco, Berkeley, downtown Oakland, the Berkeley Hills Tunnel and the Transbay Tube.

Stations: The 34 stations include 13 elevated, 14 subway and 7 at ground level. They are spaced at an average distance of 2.1 miles: stations in the downtowns are less than ½-mile apart while those in suburban areas are 2 to 4 miles apart. Parking lots at 23 stations have a total of 19,000 spaces. There is a fee (25¢) at only one of the parking lots. BART and local agencies provide bus service to all stations.

Trains: Trains are from 4 to 10 cars long. Each car is 70 feet long and has 72 seats. Top speed is 80 mph with an average speed of 38 mph including station stops. All trains stop at all stations on the route.

Automation: Trains are automatically controlled by the central computer at BART headquarters. A train operator on-board each train can over-ride automatic controls in an emergency.

Magnetically encoded tickets with values up to $20 are issued by vending machines. Automated fare gates at each station compute the appropriate fare and deduct it from the ticket value. At least one agent is present at each station to assist patrons.

Fares: Fares range from 25¢ to $1.45, depending upon trip length. Discount fares are available for the physically handicapped, children 12 and under and persons 65 and over.

Service: BART serves the counties of Alameda, Contra Costa and San Francisco, which have a combined population of 2.4 million. The system was opened in five stages, from September, 1972, to September, 1974. The last section to open was the Transbay Tube linking Oakland and the East Bay with San Francisco and the West Bay.

Routes are identified by the terminal stations: Daly City in the West Bay, Richmond, Concord and Fremont in the East Bay. Trains operate every 12 minutes during the daytime on three routes: Concord - Daly City, Fremont - Daly City, Richmond - Fremont. This results in 6-minute train frequencies in San Francisco, downtown Oakland and the Fremont line where routes converge. In the evening, trains are dispatched every 20 minutes on only the Richmond - Fremont and Concord - Daly City routes. Service is provided weekdays only, between 6 A.M. and midnight. Future service will include a Richmond - Daly City route and weekend service. Trains will operate every 6 minutes on all routes during the peak periods of travel.

Patronage: Approximately 130,000 one-way trips are made each day. 200,000 trips are anticipated under full service conditions.

Cost: BART construction and equipment cost $1.6 billion, financed primarily from local funds: $942 million from bonds being repaid by the property and sales taxes in the three counties, $176 million from toll revenues of transbay bridges, $315 million from federal grants, and $186 million from interest earnings and other sources.

SUMMARY AND CONCLUSIONS

The BART System

The 71-mile Bay Area Rapid Transit (BART) System opened in five stages. In September 1972, January 1973, and May 1973, respectively, service began from Fremont, Richmond, and Concord to Oakland on the three East Bay lines of the System; in November 1973, the West Bay line opened between Daly City and San Francisco's central business district; and in September 1974, service began on the final and key section of the System, the Transbay Tube linking San Francisco to Oakland and the other urban and suburban areas of Alameda and Contra Costa Counties. This report assesses BART's impacts on bus ridership, bus services, and highway traffic volumes and congestion in the period to October 1976, four full years after the start of service on the first BART line, and two years after the start of transbay service.

Ridership on BART

With service to all 34 stations on the System provided from 6:00 a.m. to midnight, Monday through Friday, and direct daytime service provided on three of the four planned routes, daily ridership averages about 132,000 trips per day. Of these, 42,000 (32%) are trips made between stations within the East Bay, 37,000 (28%) are trips made within the West Bay, and 53,000 (40%) are transbay trips. Ridership is heavily oriented towards peak-period travel to and from central San Francisco and Oakland. Of trips made on the System during the 18-hour operating day, 25% are made in the two hours 7:00 a.m. to 9:00 a.m. Of these, 60% exit at one of the four downtown San Francisco stations and another 17% at one of the three downtown Oakland stations. The Transbay Tube, the most heavily traveled link of the BART System, typically carries about 11,600 trips to San Francisco in the 7:00 a.m. to 9:00 a.m. peak period, but only 1,500 trips in the opposite direction in the same period.

Diversion of Ridership from Bus to BART

Of the 37,000 daily BART trips in the West Bay, about 62% or 23,000 trips have been diverted from existing transit services, nearly all from the bus and streetcar services of the San Francisco Municipal Railway (MUNI). In the East Bay, about 23% of the 42,000 daily BART trips or 10,000 trips have been diverted from bus, nearly all from the services of the Alameda-Contra Costa Transit District (AC Transit).

But BART's impacts on bus ridership have been greatest in the transbay corridor, where the System closely parallels several existing express bus services between the East Bay suburbs and San Francisco. About 28,000 trips, or 52% of BART's transbay ridership of 53,000 daily trips have been

diverted from the transbay bus services of AC Transit and Greyhound Lines. About 9,000 of these were diverted from Greyhound's commuter bus services in the Concord corridor, causing about a 75% drop in ridership on those services. The remaining 19,000 trips represent a loss of about 30% to AC Transit's transbay bus services.

In total, about 61,000 daily line-haul trips now being made on BART, or about 46% of BART's total ridership of 132,000 trips per day, have been diverted from existing transit services. (The remainder comprises 62,000 daily trips [47%] diverted from automobile and other modes and an estimated 9,000 trips [7%] which would not have been made without BART.)

Use of Bus To Get to and from BART

The 61,000 line-haul trips lost to BART have been largely offset by travelers using MUNI, AC Transit, and other local bus systems to get to and from BART stations. In San Francisco, about 17,000 trips use bus or streetcar to get to and from BART daily. In the East Bay, there are about 27,000 such access trips. (Note that these numbers are daily access trips to and from BART, with a single origin-to-destination trip on BART counting as two access trips, one from the origin to BART and one from BART to the destination. Either or both of these may be by bus.)

Net Impacts on Bus Ridership

BART's net impact on bus and streetcar ridership is summarized in the following tabulation:

	One-Way Bus and Streetcar Trips per Day		
	Loss of "Line-Haul" Trips Diverted to BART from Parallel Services	Gain of "Access" Trips Using Feeder Services To Get to and from BART	Net Loss (Gain)
MUNI San Francisco Bus and Streetcar	23,000	17,000	6,000
AC Transit East Bay Bus	10,000	27,000	(17,000)
AC Transit Transbay Bus	19,000	--	19,000
Greyhound Transbay Bus	9,000	--	9,000
Total All Services	61,000	44,000	17,000

The bus access trips gained are generally much shorter than the line-haul trips lost and produce a lower average farebox revenue per trip (largely because of a 50% discount fare for travelers transferring between MUNI or AC Transit and BART). Thus, the number of trips shown as lost are not strictly comparable to the number gained; but taking the two together shows a net BART-related loss to the existing transit systems of only 17,000 bus trips daily. This net loss represents only about 3% of the combined current daily ridership on the MUNI, AC Transit, and Greyhound systems and is so small that it is difficult to detect from time-series data on aggregate transit ridership, given growth trends and other sources of variation.

Impacts on Bus Service

Improved feeder bus service to BART in San Francisco has been provided by rerouting and increasing service on several MUNI lines, but generally, bus services paralleling BART have not been downgraded to the degree planned, largely as a result of public protest at proposals for service reduction. On no MUNI line has service been discontinued as a result of BART.

Similarly, in the East Bay, AC Transit has introduced new bus lines, rerouted existing lines, or increased service frequencies to improve feeder service to BART. In addition, AC Transit now operates, under contract to the BART District, five new "BART Express Bus" routes to and from parts of the District beyond the immediate service area of BART stations. But on only a handful of lines paralleling BART has service been reduced (and on only one line has service been discontinued altogether).

Only transbay bus lines have been obviously cut back because of losing riders to BART. Greyhound commuter bus services to San Francisco from the suburbs of central Contra Costa County, which have been largely duplicated by BART Concord Line service, have been reduced most drastically; the 80% reduction in vehicle trips is approximately in proportion to the drop in Greyhound's ridership. Greyhound has discontinued all its off-peak service in the Concord corridor since transbay BART service began.

AC Transit's transbay services have been cut back much less severely as a result of BART's starting service. This is explained by the fact that AC Transit's transbay services effectively operate as "local" collector services within the East Bay and then as "express" buses across the San Francisco-Oakland Bay Bridge. Even where the bus lines parallel BART, they continue to provide a more convenient, no-transfer, and often faster journey for many travelers. Total scheduled bus-miles on AC Transit transbay lines have been reduced only by about 15% in the year after transbay BART service began, and on the bus lines experiencing the greatest reduction (the lines paralleling Fremont-San Francisco BART service) headways have only increased from about 5 minutes to 10 minutes in the peak period.

San Francisco Bay Bridge Traffic Volumes

One of the key highway links in the Bay Area is the San Francisco-Oakland Bay Bridge (generally referred to as the Bay Bridge). Typically, well over 90,000 vehicles per day travel on the five lanes of the bridge in each direction, and BART service through the Transbay Tube parallel to the Bay Bridge was expected to have major impacts on its traffic. This report focuses on time-series analyses of traffic volumes on the Bay Bridge, using the three other bridges across San Francisco Bay, on whose traffic volumes BART has had little or no effect, as "control" sites. The other bridges are the Golden Gate Bridge which, like the Bay Bridge, carries high volumes of commuter traffic to and from San Francisco, the San Mateo-Hayward Bridge, and the Richmond-San Rafael Bridge.

Trend and Seasonal Variations

Daily midweek traffic volumes on all four bridges have shown steady growth trends and consistent patterns of seasonal variation for several years. Using linear regression analysis, these trend and seasonal components of traffic volumes were estimated and projected forward to give "baseline" estimates of traffic volumes to compare with actual traffic volumes on the bridges. These projections represent the traffic volumes which would have arisen if the trend and seasonal patterns of previous years had continued unchanged. It follows that the difference between the projections and actual traffic volumes represent changes in traffic which must be explained by factors other than trend and seasonal influences. In the last three years, the most important influences have been the gasoline shortages of early 1974 and accompanying increases in gasoline prices, and on the Bay Bridge, the start of transbay BART service in September 1974.

Changes in Highway Traffic Volumes

Comparing projected and actual Bay Bridge traffic volumes over the two years since transbay BART began shows an average reduction of about 3,000 vehicles per day in each direction. This reduction, although representing the combined effects of BART and gasoline price increases, is very much smaller than had been anticipated for BART alone. It is also small relative to total Bay Bridge traffic volumes, representing less than 4% of average midweek daily traffic. For several years, volumes have increased by close to 2,000 vehicles per day in each direction, thus the reduction equals only between one and two years normal traffic growth. Daily Bay Bridge traffic volumes in mid-1976 were, in fact, considerably higher than they were three years previously (before either the "gasoline crisis" or BART).

When expressed as a percentage of total traffic, the reduction in traffic on the Bay Bridge (due to the combined effects of BART and gasoline price

increases has been much less than the corresponding percentage reduction on the other three bridges. This is surprising, since BART has had little or no traffic-reducing effect on the other bridges, leaving only gasoline price increases to explain their traffic reductions.

Diversion of Travel from Automobile to BART

Of the 53,000 transbay BART trips made daily, an estimated 40% or 21,000 trips would be made by automobile if BART were not available. Assuming an average automobile occupancy of 1.4 persons per vehicle, this suggests that BART has removed about 7,000 vehicles per day from the Bay Bridge in each direction.

Effects of Gasoline Price Increases

Comparing the two-year period prior to September 1973 (before the "gasoline crisis") with the two-year period after September 1974 shows that gasoline prices increased by $0.08 per gallon (expressed in constant 1967 dollars). Regression analysis of traffic volumes on the Golden Gate, San Mateo-Hayward, and Richmond-San Rafael Bridges suggest that this increase in gasoline price has had a significant and sustained traffic-reducing effect on those bridges.

The short period between the gasoline price increases of early 1974 and the start of transbay BART in September 1974, together with the disruptive effects of an AC Transit bus strike in the two months immediately before transbay BART's opening, makes it impossible to estimate reliably the effects of gasoline price on Bay Bridge traffic. But it appears clear that, here too, price increases have contributed significantly to reducing traffic volumes relative to projected levels.

Effects of Induced Automobile Traffic

The sum of the reductions in Bay Bridge traffic estimated as associated with gasoline price increases and BART's introduction is in excess of 9,000 vehicle trips per day in each direction. However, as noted, the observed reduction in traffic amounts only to about 3,000 trips per day. The difference between the two, amounting to about 6,000 vehicle trips per day, is apparently new or "induced" transbay trips via the Bay Bridge. Initial reductions in traffic caused by BART and gasoline price increases have given rise to lessened traffic congestion on the previously heavily traveled Bay Bridge. This, in turn, has effectively relaxed capacity constraints and induced previously suppressed trips to be made more frequently, or caused trips to be diverted from other destinations and routes. On the Bay Bridge, this induced traffic appears to have almost completely offset BART's contribution to reducing traffic volumes.

Evidence on highway traffic volumes through the Caldecott Tunnel, which parallels the BART Concord Line point to the same conclusion: BART-caused reductions in traffic have been largely offset by induced vehicle trips, with the result that net traffic reductions due to the combined effects of BART and increased gasoline prices are equaling about a one-year shift in the long-term trend.

BART Impacts on Traffic Congestion

Corresponding to the small net reductions in traffic vehicle volumes, BART has had little impact on highway travel times and traffic congestion. For Bay Area highways, available data indicate a measurable BART-related reduction in congestion only on the San Francisco-Oakland Bay Bridge; and even there, the effect has been short-lived. Statistically, congestion was significantly lower in the spring of 1975 than it was a year earlier, with the period of heaviest morning congestion being shorter and occurring slightly later. But between the two years, the average time taken to cross the Bay Bridge during the morning peak period differed by only about 1-1/2 minutes; and by the spring of 1976, congestion levels were well above spring 1974 levels.

BART Impacts on Total Travel

The estimated 6,000 "induced" automobile vehicle-trips made daily across the Bay Bridge in each direction correspond to about 8,000 person-trips. To these must be added an estimated 2,000 new transbay trips being made on BART--trips which would probably not be made if BART were not running under the Bay. The assumptions of our analysis are such that the resulting total of around 10,000 daily transbay trips in each direction is probably a low estimate of the total number of induced trips. Nevertheless, the estimate represents a large volume of travel.

The predictions that BART would reduce traffic volumes and congestion dramatically on the Bay Bridge have not been fulfilled. Instead, by increasing the total transportation capacity of a previously capacity-constrained corridor, BART's principal effect has been to allow previously suppressed trips to be made (both by automobile and on BART), with the net result that total travel in the corridor increased substantially.

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I. INTRODUCTION

The BART System

A map of the 71-mile, 34-station BART System is shown in Figure I-1. The System lies within the three Bay Area counties of San Francisco, Alameda, and Contra Costa, except for about 0.2 miles of line and the Daly City BART Station which are in San Mateo County. Four BART lines radiate from the central Oakland section of the System. These are the Concord, Richmond, Fremont, and Daly City Lines to the east, north, south, and west, respectively.

BART service was introduced in the following stages:

- September 11, 1972--Opening of the Fremont Line
- January 29, 1973--Opening of the Richmond Line
- May 21, 1973--Opening of the Concord Line
- November 5, 1973--Opening of the Daly City Line to San Francisco's central business district
- September 16, 1974--Start of transbay BART service
- November 28, 1975--Start of evening service 8:00 p.m. to midnight

Currently, three direct BART services are operated: Fremont-Daly City, Concord-Daly City, and Fremont-Richmond.* Service is operated on the three routes from 6:00 a.m. to approximately 6:30 p.m., Monday through Friday. In the evening between 6:30 p.m. and approximately 12 midnight, trains operate on only two routes, Richmond-Fremont and Concord-Daly City. Patrons can transfer between the two routes at any of the three Oakland stations. Scheduled headways between trains are 12 minutes on each of the three services until the end of the afternoon peak period, after which headways are scheduled at 20 minutes. (The combined headways on the Daly City and Fremont Lines are thus 6 minutes during daytime hours of operation. Trains vary in length by line and time of day, with a maximum train length of 10 cars (720-seat capacity). Planned future service improvements include extending the hours of operations to 20 hours (5:00 a.m. to 1:00 a.m.); providing all-day direct Richmond-Daly City service; providing weekend service; reducing headways; and adjusting the train sizes as required to serve passenger demands.

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*In addition, one train a day runs in each direction between Richmond and Daly City to provide service to a major federal office building in Richmond. Direct service throughout the day is planned for Richmond and Daly City, but at present, travelers between stations on the Richmond and Daly City lines must transfer.

FIGURE I-1

BAY AREA RAPID TRANSIT SYSTEM

The Highway System

As shown in Figure I-2, each of the BART lines more or less parallels a major freeway. The Daly City Line parallels I-280 and Route 101, the Richmond Line I-80, the Concord Line Route 24, and the Fremont Line Route 17 (and to a lesser extent I-580). Oakland and the other East Bay cities are linked to the San Francisco Peninsula and Marin County by three major highway toll bridges: the San Francisco-Oakland Bay Bridge (generally known as the Bay Bridge), the San Mateo-Hayward Bridge, and the Richmond-San Rafael Bridge. The other major highway links highlighted in Figure I-2 are the Golden Gate Bridge linking Marin County to San Francisco; and the Caldecott Tunnel on Route 24 through the Berkeley Hills linking central Contra Costa County to Berkeley, Oakland, and the Bay Bridge. Characteristics of these five key highway links are:

Highway Link	Total Lanes in Both Directions	Total Toll Charge for Both Directions[a]	Average Daily Vehicles in Both Directions
San Francisco-Oakland Bay Bridge	10	$0.50/$0.40	190,000
San Mateo-Hayward Bridge	4 (6 at center span)	$0.70/$0.40	30,000
Richmond-San Rafael Bridge	6	$1.00/$0.60	20,000
Golden Gate Bridge	6	$0.75	100,000
Caldecott Tunnel	6	None	100,000

a. The first number is the normal toll for passenger cars; the second is the charge for prepaid commuter ticket books. Tolls are paid in the westbound (or southbound) direction only. On the Bay Bridge, San Mateo Bridge, and Golden Gate Bridge, cars containing three or more persons pay no toll at peak periods. (This has recently been extended from 6:00 a.m. to 6:00 p.m. on the Bay Bridge.)

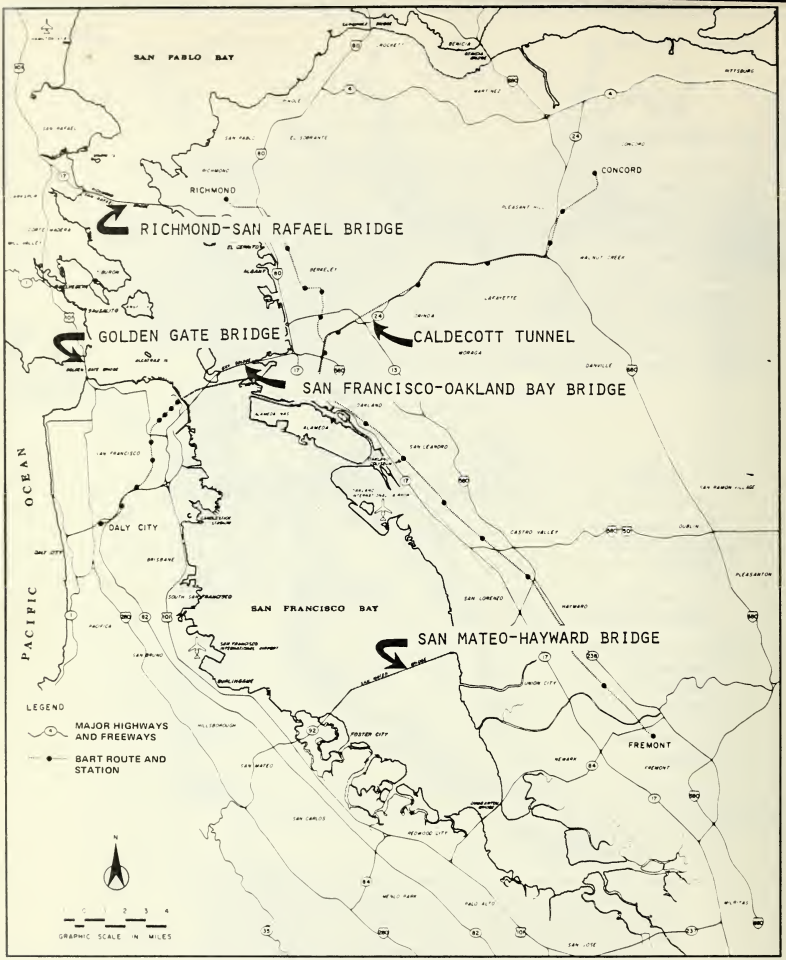

FIGURE I-2

HIGHWAY BRIDGES ACROSS THE SAN FRANCISCO BAY

The most important of these is the San Francisco-Oakland Bay Bridge which parallels the BART Transbay Tube and connects the freeways of the San Francisco Peninsula and the employment centers of San Francisco directly to Oakland and the major freeways leading to the industrial and residential areas of the East Bay. The four freeways radiating from the eastern terminus of the Bay Bridge (I-80, Route 24, I-580, and Route 17) have a total of 32 lanes in both directions where they begin.

Other Transit Services

The area served by BART is also served by a number of other transit operators.

Alameda-Contra Costa Transit District (AC Transit). As the major bus operator in the East Bay, AC Transit provides bus service in the cities west of the Berkeley and San Leandro Hills from Richmond in the north to Fremont in the south, an area of over 200 square miles with a population of over a million. All 20 BART stations on the Richmond and Fremont Lines, the Rockridge Station on the Concord Line, and the West Oakland Station on the Daly City Line are in this AC Transit service area. Also, AC Transit recently began operating local bus services in areas of central Contra Costa County east of the Berkeley Hills (served by the BART Concord Line). AC Transit buses now connect with BART at the Concord, Pleasant Hill, Walnut Creek, Lafayette, and Orinda Stations.

In addition to local and express bus service in the East Bay, AC Transit operates extensive bus routes across the San Francisco-Oakland Bay Bridge to the transbay bus terminal on the edge of downtown San Francisco.

Under contract to the BART District, AC Transit also operates "BART Express Bus" service to and from those portions of the BART District beyond the immediate service area of BART stations. Service on five Express Bus routes began in late 1974: from the Pinole area of northwestern Contra Costa County to the El Cerrito del Norte BART Station (Q Line); from Dublin, San Ramon, Danville, and Alamo to the Walnut Creek Station (D Line); from Martinez and Pleasant Hill to the Concord Station (M Line); from Brentwood, Oakley, Antioch, Pittsburgh, and West Pittsburg to the Concord Station (P Line); and from Livermore, Pleasanton, Dublin, and San Ramon to the Hayward and Bay Fair Stations (U Line).

At the end of fiscal year 1976, AC Transit operated a fleet of 820 buses on 168 lines with a total one-way route mileage of 1,986 miles.

San Francisco Municipal Railway (MUNI). MUNI provides bus, trolley, streetcar, and cable car service to the entire City of San Francisco, an area of 46 square miles with a population of slightly under 700,000. The

City is served by eight of nine stations on the Daly City BART Line. The ninth station, Daly City, is in San Mateo County, but is served by one MUNI bus line. At the end of fiscal year 1975, MUNI operated a fleet of 1,029 vehicles--542 buses, 333 trolley coaches, 115 streetcars, and 39 cable cars. Seventy-three lines were operated over a one-way route mileage of 805 miles.

Greyhound Bus Lines. Greyhound commute buses serve the area east of the Berkeley Hills in central Contra Costa County, which is also served by the BART stations on the Concord Line (except Rockridge). Greyhound commuter service consists mainly of express service between terminals in Orinda, Lafayette, Walnut Creek, Concord, and downtown San Francisco. As discussed later, transbay BART service has greatly reduced Greyhound ridership, and Greyhound has filed a request with the State of California Public Utilities Commission to discontinue the service. Greyhound's Vallejo-San Francisco route provides service through Pinole, parallel to BART's Express Bus Q Line.

Greyhound also operates bus service between cities in San Mateo County and San Francisco, but for the most part, these services are outside the area of BART's potential influence.

Southern Pacific Railroad. Southern Pacific provides commuter rail service between San Francisco and cities on the San Francisco Peninsula in San Mateo and Santa Clara Counties. Weekday ridership to and from San Francisco averages about 16,000 trips. Again, the area served by Southern Pacific is only marginally served by BART, and interaction between the two systems is small.

Golden Gate Transit. Besides furnishing bus service within Sonoma and Marin Counties, Golden Gate Transit's fleet of about 250 buses offers express bus service across the Golden Gate Bridge to downtown San Francisco from many communities in Marin and central Sonoma Counties. Golden Gate Transit also runs daily ferryboat service to the Ferry Building on the edge of downtown San Francisco from two terminals in Marin County. These services are effectively outside the area of BART's potential influence.

Other Bus Services Connecting with BART. Some feeder bus service is provided to all BART stations. As described, AC Transit operates most of the feeder bus service in the East Bay. In addition, city- and privately operated bus systems serve the Walnut Creek and Union City Stations and

Humphrey Go-BART provides a free shuttle bus service between the Berkeley Station and points on the University of California campus. The Santa Clara County Transit System operates one route to the Fremont Station; Peerless Stages also provides service to and from the Fremont Station. A minibus service operates across the Richmond Bridge from San Rafael to the Richmond BART Station.

In the West Bay, the MUNI system runs feeder services to all nine BART stations. The San Mateo County Transit District (SamTrans) provides direct connecting bus service between the Daly City Station and points in northern San Mateo County including Daly City, San Francisco International Airport, San Bruno, and South San Francisco. Several small shuttle buses also furnish service to Daly City from nearby apartment and townhouse complexes. Privately owned minibuses operate a "jitney" service on Mission Street between downtown San Francisco and Daly City, closely paralleling BART.

Franciscan Lines operates limited transbay commute service from Livermore to San Francisco, parallel to the BART Express Bus U Line; and from Danville to San Francisco, parallel to the BART Express Bus D Line.

Transfer Procedures. Travelers using AC Transit or MUNI to connect with BART pay only half the normal round-trip bus fare, but different transfer procedures apply for the two systems. AC Transit passengers pay the regular bus fare for their trip to the BART station. On their return trip, they can obtain a free transfer ticket in the BART station for a bus ride to any destination within the same fare zone. MUNI passengers can purchase a two-part ticket for the price of one regular ticket ($0.25) in BART stations. One part of the ticket is valid for the transfer from BART to MUNI, and the second part is valid for a return trip. The ticket bears the name of the BART station where it was issued and is valid for three days.

Objectives of Analysis

Early planning reports for the BART System predicted that diversion of travel to BART, especially from automobile, would effect major reductions in highway travel volumes and peak period traffic congestion in corridors served by the System. Changes in bus service and ridership levels were also anticipated. The objective of this report is to analyze data on service levels and aggregate passenger travel by BART, bus, and automobile in order to assess (1) what changes in travel volumes by bus and automobile have taken place over the four-year period since BART's introduction, (2) what changes in bus service and highway congestion levels have occurred over the same period, and (3) the extent to which these changes may be attributed to BART. It should be emphasized that:

1. The analysis deals only with aggregate travel data, e.g., counts of vehicle traffic volumes, counts of transit ridership, and observations of traffic congestion levels. The analysis does not attempt to assess changes in travel behavior or the reasons for these changes based on analysis of a travel interview survey or other disaggregate data.*

2. The analysis deals mainly with selected highways and transit links, particularly the bridges across San Francisco Bay. It does not attempt a comprehensive analysis of BART's effects on highway vehicle-miles of travel or other measures of areawide travel volume.

The report covers the period to October 1976. This is four full years after the start of BART service (on the Fremont Line) and two years after the start of transbay service.

Factors Changing Travel Patterns

BART's impacts on travel by all modes, and especially travel by automobile, must be considered in the context of other influences affecting travel patterns over the period since BART service started. Long-term changes in highway traffic have been brought about by the growth of the urban area, its population, economy, and automobile ownership. These influences caused a growth trend in traffic which was recently modified by the gasoline shortages of early 1974 and associated increases in gasoline prices.

The start of service on the BART System has changed highway traffic and bus ridership volumes, as have other events, including improvements in bus service, changes in the relative prices of travel by transit and automobile, transit strikes, and the opening of new highway facilities. Table I-1 chronologically lists some of the more important events. Variations about the trend have also occurred as a function of the month of the year, reflecting vacation patterns and seasonal business cycles. Finally, day-to-day variations in travel have occurred as a function of day-of-the-week, weather, public holidays, and so on.

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*Other reports of the Transportation System and Travel Behavior Project will deal with these aspects.

Table I-1

SELECTED EVENTS AFFECTING BAY AREA TRAVEL PATTERNS, 1972-1976

1972	January	Route I-280 from Peninsula to San Francisco opened
	September	BART Fremont Line opened
1973	January	BART Richmond Line opened
	March	Golden Gate Bridge toll increased
	May	BART Concord Line opened
	July-August	BART strike
	November	BART Daly City Line opened to San Francisco
	September-March	Major gasoline price increases
1974	January-March	Gasoline shortages
	January	Maximum speed limit reduced to 55 mph
	March	Metering system on Bay Bridge operational
	March	San Francisco workers strike closed MUNI
	July-August	AC Transit strike
	September	BART transbay service began
	December	BART extension "Express Bus" service began
1975	March	Bay Bridge toll eliminated for car pools
	November	BART fares increased
	November	BART evening service 8 p.m. to 12 midnight
1976	March-May	San Francisco workers strike closed MUNI
	April-June	Golden Gate Transit strike
	May	BART Embarcadero Station opened

The gasoline shortage in 1974 and the associated rise in gasoline prices have been among the most important influences on automobile travel. Figure I-3 shows a time series of regular gasoline prices in the Bay Area. The time series is a composite of data for a sample of gas stations in San Francisco as published in Platt's Oil Fact Book (from September 1972 to September 1973) and data published by the U.S. Department of Commerce for the five-county San Francisco-Oakland Standard Metropolitan Statis- Statistical Area (from October 1973 onwards). The table also shows the price data series expressed in constant (1967) prices using the U.S. Department of Commerce Consumer Price Index as the deflation factor.

The first time series shows that the price of gasoline in San Francisco in September 1972, when the first BART line opened, was about $0.37 per gallon. The price remained at about this level until the summer of 1973, but in the six months from September 1973 to March 1974, it rose from $0.38 per gallon to $0.54 per gallon, an increase of 42%. From March 1974, the price rose less steeply to $0.57 per gallon in March 1975 and $0.60 per gallon in March 1976. In September 1976, the average price of regular gasolene was $0.64, an increase of 73% over the price four years before. Expressed relative to the prices of other consumer goods, the increase in gas prices has not been so dramatic, but is still large. The 1967 dollar price of a gallon of regular gas increased from $0.28 in September 1973 to $0.37 in September 1976 a 32% increase).

Data Sources

The analyses of this report are based on data collected from several sources. The most important of these are given below.

California Department of Transportation (CALTRANS), Toll Bridge Administration, Traffic Volume Counts. Volume counts are maintained by CALTRANS on a continuing basis for westbound vehicle traffic crossing the San Francisco-Oakland Bay Bridge, the San Mateo-Hayward Bridge, and the Richmond-San Rafael Bridge. These "totalizer counts" are counts of vehicles (not classified by type) for each lane of the toll plaza summarized by time period (normally hourly, but sometimes at more frequent intervals). Strictly, the counts are for toll transactions, rather than vehicles, with the exception of the special priority bus lane on the Bay Bridge where vehicles do not stop to pay a toll and where mechanical (axle) counts are recorded. The totalizer volume counts are routinely summarized by the Toll Bridge Administration on a daily basis. Summary distributions of traffic on an hourly basis are also prepared by the Toll Bridge Administration from time to time. In addition to these summaries, the TSTB Project abstracted further detailed volume data from the original totalizer printout records.

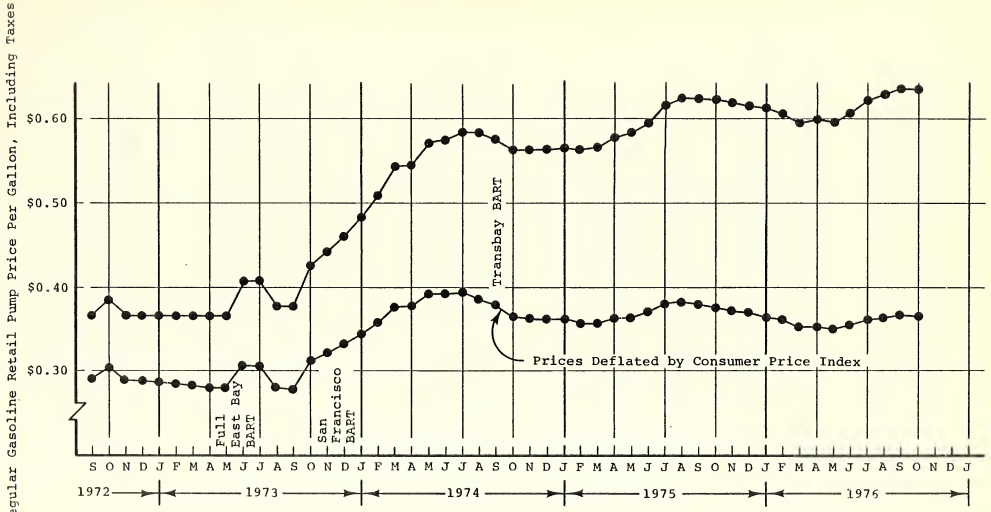

FIGURE I-3

CHANGES IN GASOLINE PRICES,
SAN FRANCISCO-OAKLAND METROPOLITAN AREA, SEPTEMBER 1972 - OCTOBER 1976

Sources:
- Platt's Oil Fact Book (San Francisco County to September 1973).
- U.S. Department of Labor (San Francisco-Oakland SMSA from October 1973).
- U.S. Department of Commerce, Survey of Current Business (Consumer Price Index).

Golden Gate Bridge, Highway and Transportation District, Traffic Volume Counts. The Golden Gate Bridge District Traffic Department maintains and reports comprehensive vehicle counts on a day-by-day basis, classified by vehicle type. These are records of toll transactions for southbound traffic across the bridge.

Other Traffic Volume Counts. Over the years, large numbers of traffic volume counts on Bay Area highways have been taken by CALTRANS and by the Metropolitan Transportation Commission (MTC). However, as discussed in Chapter IV, very little of these data have proved useful for assessing BART's influence on traffic volumes.

BART Ridership Counts. Counts of passengers entering and exiting the automatic faregates at BART stations are continuously recorded by BART's Data Acquisition System (DAS). The DAS records ridership by time-of-day and by station, allowing detailed analysis of origin-destination travel volumes as presented in the following chapter.* Estimates of BART ridership through the Transbay Tube and through the BART link paralleling the Caldecott Tunnel have also been made semi-annually by the University of California Institute of Transportation Studies** since BART service began (as discussed below).

Bart Ridership Surveys. Each year since the start of BART service, on-board inverview surveys of riders have been conducted by the BART District and MTC. These BART Passenger Profile Surveys provide information on BART riders' previous mode of travel (as summarized in Chapter II) and their modes of access to and from BART stations (analyzed in Chapter III).

Bus Ridership Counts. Day-by-day, AC Transit records estimates of passengers carried on all their bus lines including transbay lines and BART Express lines. San Francisco MUNI summarizes estimates of aggregate ridership on their bus, trolley, streetcar, and cable car services quarterly. Ridership on individual lines is not recorded except in occasional special-purpose counts. Greyhound Lines makes periodic counts of ridership on its Contra Costa County commute services from Concord, Walnut Creek, Danville, and Lafayette. The counts do not comply with any regular schedule, but are recorded and submitted to the California Public

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*Strictly, the DAS records only exits, and then sorts them by coded entry to separate entries by station. Actual entry counts may be possible in the near future by modifying the faregate mechanism. The DAS has been fully operational only since the beginning of 1976. Before then, detailed time-of-day and origin-destination data are not available.

**Formerly the Institute of Traffic and Transportation Engineering (ITTE).

Utilities Commission as required. Golden Gate Transit maintains comprehensive records of ridership on their bus services, including commute services from Marin and Sonoma Counties to San Francisco.

University of California, Institute of Transportation Studies (ITS), Semiannual Travel Surveys. Based on the above data sources as well as their own surveys, ITS has for many years compiled summaries of traffic across the San Francisco-Oakland Bay Bridge on typical weekdays in April and October. Traffic volumes are summarized for both westbound and eastbound vehicle volumes over the 24-hour day. For the 12-hour period 6:30 a.m. to 6:30 p.m., vehicle volume counts are classified by vehicle type; automobile occupancy and bus occupancy counts are also recorded. Passenger volumes on AC Transit buses, Greyhound buses, and BART are also recorded in both directions of travel, distributed over the day.

Similar long-term records of traffic and travel volumes through the Caldecott Tunnel on Route 24 in April and October have also been maintained by ITS. Since 1973, the ITS survey programs for the Bay Bridge and Caldecott Tunnel have been supported by the BART Impact Program.

Highway Travel Time Surveys. A series of highway travel time surveys were undertaken by the TSTB Project in May and June 1975. These surveys were conducted by the "moving-car observer" method in which the driver of the survey vehicle adjusts his speed to the norm of the vehicles around him. Travel times were recorded manually by the second member of the survey crew. Data were observed only on Tuesdays, Wednesdays, and Thursdays during the morning (6:30 a.m. to 9:30 a.m.) and evening (3:30 p.m. to 6:30 p.m.) peak periods. These formed the "post-BART" data which were compared with corresponding "moving-car observer" data collected by CALTRANS "pre-BART" between 1971 and 1974.*

Bay Bridge Metering System. In March 1974, a system of traffic lights became operational on the Bay Bridge to meter the flow of vehicles entering the bridge lanes from the toll plaza. (See Chapter VI for a more complete description.) The period of activation of the metering system, which indicates the length of the congested period, has been recorded day-by-day by the CALTRANS Toll Bridge Administration since the system started.

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*Some of the CALTRANS data were recorded on tachographs (rather than using two-man survey crews). Tachographs are devices which, when actuated, simultaneously record elapsed time and distance from the survey starting point.

Organization of the Report

The organization of the remainder of the report into chapters attempts to conform to the following "conceptual framework" of the way in which transportation impacts arise: BART directly changes the characteristics of transportation service provided. In response to these changes, travelers divert to BART from bus and automobile, giving rise to changes in the pattern of travel on the transportation system. These may be termed travel impacts. In addition, diversion of travel to BART causes changes in the level of service provided by the rest of the transportation system. These may be termed system impacts.

Chapter II describes aggregate BART ridership on the System in terms of its historical development, origin-destination distribution, and distribution over the hours of the day. The previous travel mode of BART riders is also analyzed.

Chapter III describes changes in aggregate ridership on buses (and other transit modes) in the Bay Area, and discusses the extent to which (1) diversion of travel from bus to BART and (2) the use of buses to get to and from BART may have been responsible for some of the changes. Changes in bus service resulting from BART's introduction are also analyzed.

Chapter IV describes changes in automobile traffic volumes, focusing on the four major bridges across San Francisco Bay, particularly the one most affected by BART (the Bay Bridge), and the Caldecott Tunnel. The analysis attempts to separate the impacts of diversion of travel from automobile to BART from the effects of changes in gasoline prices, seasonal variations, and other confounding factors.

Chapter V extends the "travel impacts" analyses of Chapter IV by analyzing historical total person-travel in the Bay Bridge corridor by private automobile, bus, and BART. Total person-trips in the Caldecott Tunnel corridor are also analyzed historically.

The major anticipated "system impacts" of BART are changes in the service provided by the highway system. Chapter VI describes changes in peak period highway congestion including analysis of the volume of traffic occurring during the peak, and highway travel times. The analysis again focuses on the Bay Bridge and other key highway links where BART was expected to have an impact.

II. BART RIDERSHIP

Historical BART Ridership

Figure II-1 shows average daily ridership on the System since the start of service on the Fremont Line in September 1972. In October 1973, when only the three East Bay lines were in operation, average daily ridership was about 36,000 trips. This increased to 68,000 with the start of service on the line between San Francisco and Daly City. Following the start of transbay service in September 1974, average daily ridership on the System increased to about 120,000 trips, and from then until March 1976, average ridership remained at about this level (varying between 114,000 and 128,000 trips daily).

Following an increase in BART fares effective November 3, 1975, average daily ridership decreased from 125,000 trips in October to 121,000 trips in November. Following the start of evening service on November 28, 1975, average daily ridership increased from 121,000 trips in November to 128,000 trips in December 1975.

During the months of April and May 1976, MUNI buses were not providing service because of a strike of San Francisco city craft workers (from March 31 through May 8, 1976). Consequently, average daily ridership increased from 123,000 trips in March to 145,000 trips in April 1976, with all of this increase occurring in West Bay ridership. Since the MUNI strike and the opening of the BART Embarcadero Station on May 27, 1976, average daily ridership on the System has remained fairly steady, varying between 130,000 and 132,000 trips per day over the last five months shown in Figure II-1. Most of the increase in ridership between the beginning of 1976 and the last points shown is probably attributable to opening the Embarcadero Station, but residual effects of the MUNI strike may account for some of the increase.

From the start of the transbay service in September 1974 until October 1976, East Bay ridership changed very little, with monthly averages varying between 37,000 and 43,000 trips per day. Similarly, transbay ridership remained fairly steady, with monthly averages varying between 49,000 and 57,000 trips per day. Only in the West Bay has any sustained overall increase in ridership been apparent, and this is mostly due to opening the Embarcadero Station. For the first five months June to October 1975, West Bay ridership averaged 28,000 trips per day; for the same five months in 1976 the average was 37,000 trips per day.

In October 1976, the distribution of average daily riderhsip was: East Bay 32% (42,000 trips), West Bay 28% (37,000 trips), transbay 40% (53,000 trips).

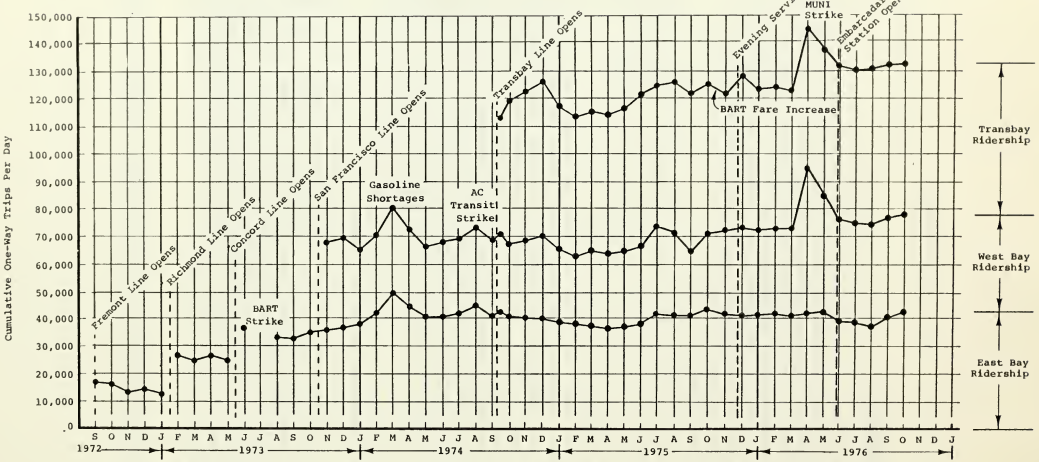

FIGURE II-1

AVERAGE DAILY BART RIDERSHIP, SEPTEMBER 1972 - OCTOBER 1976

Source: BARTD Office of Research, Monthly BART Patronage Reports.

Geographical Distribution

Origin-Destination Patterns. Tables II-1, II-2, and II-3 are matrices of station-to-station BART ridership for a typical midweek day in October 1976 for (1) total all-day ridership, (2) morning peak period (7:00 a.m. to 9:00 a.m.)* ridership, and (3) evening peak period (4:00 p.m. to 7:00 p.m.) ridership, respectively. Each table has two parts. The data shown were summarized from output of BART's DAS. The DAS automatically records exits through all faregates at BART stations by time of day and location.

The three tables show a total of 129,900 BART trips made during the entire operating day (6:00 a.m. to 12 midnight); 32,600 (25%) of these exiting the System during the two hours from 7:00 a.m. to 9:00 a.m. and 43,100 (33%) exiting during the three hours from 4:00 p.m. to 7:00 p.m.

Especially for the morning peak, the tables show the orientation of BART travel to the downtown stations. A total of 19,600 trips exits from the four downtown San Francisco stations (Embarcadero, Montgomery, Powell, and Civic Center) during the two hours from 7:00 a.m. to 9:00 a.m. These represent 60% of all trips exiting the System during the period. A further 5,400 trips (17%) exit from the three downtown Oakland stations (19th Street, 12th Street, and Lake Merritt). A high proportion of these downtown trips are made from stations on the Concord Line and from the three outlying San Francisco stations.

Link Flows between Stations. Table II-4 shows ridership on the links of the System between adjacent stations (as derived from the origin-destination matrices of Tables II-1, II-2, and II-3). Ridership is shown by direction of travel and for morning peak (7:00 a.m. to 9:00 a.m.) and evening peak (4:00 p.m. to 7:00 p.m.) periods as well as for total all-day ridership on each link.

This table also shows the downtown orientation of much of BART travel and illustrates the imbalance between flows in opposite directions on some links of the System at the peak periods. For example, ridership through the Transbay Tube to San Francisco in the morning peak (7:00 a.m. to 9:00 a.m.) totals 11,600 trips, but only 1,500 trips are made through the Tube in the opposite (eastbound) direction during the same period. This is a 89%/11% split. On the link between Orinda and Rockridge (paralleling the Caldecott Tunnel) during the morning peak, 7,900 trips flow in the peak direction compared to 600 trips in the reverse direction (a 93%/7% split).

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*Times given are times of exit from the System.

Table II-1 (Part 1)

STATION-TO-STATION BART RIDERSHIP, AVERAGE DAY, OCTOBER 1976, TOTAL ALL-DAY RIDERSHIP

Destination	Origin																	
	Lake Merritt	Fruit-vale	Coli-seum	San Leandro	Bay Fair	Hayward	South Hayward	Union City	Fremont	12th St Oakland	19th St Oakland	Mac-Arthur	Oakland West	Rock-ridge	Orinda	La-fayette	Walnut Creek
Lake Merritt	22	91	87	94	122	154	79	85	131	41	46	46	34	34	7	11	32
Fruitvale	111	25	56	95	119	223	84	68	106	140	178	37	18	15	16	14	21
Coliseum	125	66	7	34	82	129	60	62	119	158	135	39	30	14	12	8	23
San Leandro	99	119	33	12	69	161	97	68	89	210	297	40	17	17	7	10	15
Bay Fair	127	115	73	67	14	71	39	93	170	222	346	44	28	11	3	5	11
Hayward	159	229	131	193	75	19	70	178	305	224	300	66	32	24	10	12	27
South Hayward	88	78	42	91	41	73	7	64	114	106	180	26	17	6	2	2	4
Union City	96	70	60	73	97	185	120	20	94	126	221	42	27	4	3	2	7
Fremont	164	102	114	92	166	329	172	106	43	145	250	49	28	16	9	5	16
12th St Oakland	104	159	196	239	259	254	142	172	202	13	41	60	25	61	103	115	174
19th St Oakland	82	142	122	289	321	289	185	232	268	39	16	67	20	73	143	226	292
MacArthur	58	42	25	28	41	56	26	23	41	58	75	5	11	24	51	38	66
Oakland West	32	17	25	14	28	22	15	23	31	19	21	10	1	8	6	5	9
Rockridge	33	10	14	11	11	22	7	3	11	63	82	18	10	7	113	98	153
Orinda	7	14	12	4	4	12	3	2	11	83	127	55	6	80	8	24	56
Lafayette	12	13	9	8	4	12	2	3	6	107	196	44	6	74	28	5	57
Walnut Creek	37	20	26	13	11	26	4	7	17	159	284	60	8	117	55	51	25
Pleasant Hill	39	15	17	8	5	17	4	4	12	111	269	42	20	72	58	58	84
Concord	29	37	40	23	11	28	11	11	26	205	281	96	20	83	76	84	198
Ashby	129	39	37	23	18	54	8	13	20	55	83	11	4	5	10	8	12
Berkeley	353	218	125	104	128	205	86	132	210	295	303	117	16	20	63	81	128
North Berkeley	98	30	21	17	11	35	8	7	10	97	122	27	4	4	7	10	28
El Cerrito Plaza	43	30	21	25	20	38	9	11	17	100	178	47	6	5	8	9	13
El Cerrito del Norte	44	38	26	24	15	46	5	13	24	124	242	58	7	11	6	9	14
Richmond	51	67	55	20	25	41	16	17	37	100	118	68	12	8	7	10	15
Embarcadero	119	142	63	114	220	169	137	273	361	186	192	117	282	173	310	330	569
Montgomery	295	319	119	206	366	313	203	327	450	359	368	245	545	356	494	578	881
Powell	160	224	92	122	165	173	74	105	257	350	281	194	167	214	111	129	289
Civic Center	138	207	80	103	172	147	75	102	189	245	177	184	169	224	91	117	247
16th St Mission	25	32	16	10	25	18	15	22	30	49	39	25	18	24	8	11	23
24th St Mission	24	37	20	13	10	22	9	15	29	50	54	25	13	24	7	13	28
Glen Park	12	11	16	11	6	16	5	10	11	31	32	8	9	8	8	8	10
Balboa Park	24	39	24	15	7	16	8	18	16	33	40	32	16	36	16	14	21
Daly City	29	23	40	13	14	19	6	8	25	67	90	30	23	33	13	19	43
Total	2,968	2,820	1,844	2,208	2,682	3,394	1,791	2,297	3,482	4,370	5,664	2,034	1,649	1,885	1,869	2,119	3,581

Note: Trips shown on the diagonal are excursion rides.

Source: BARTD Data Acquisition System, Summary of Faregate Counts for October 21, 1976.

Table II-1 (Part 2)

STATION-TO-STATION BART RIDERSHIP, AVERAGE DAY, OCTOBER 1976, TOTAL ALL-DAY RIDERSHIP

Destination	Origin: Pleasant Hill	Concord	Ashby	Berkeley	North Berkeley	El Cerrito Plaza	El Cerrito del Norte	Richmond	Embarcadero	Montgomery	Powell	Civic Center	16th St Mission	24th St Mission	Glen Park	Balboa Park	Daly City	Total
Lake Merritt	38	25	135	297	126	49	40	51	133	240	226	160	24	24	11	27	22	2,744
Fruitvale	15	31	44	228	31	36	43	59	125	303	300	219	33	37	11	36	28	2,905
Coliseum	13	42	44	128	32	20	32	49	59	129	118	93	18	22	15	22	39	1,978
San Leandro	9	25	25	112	20	24	25	22	102	207	167	113	14	16	7	15	15	2,278
Bay Fair	6	14	18	142	9	16	13	28	208	365	248	166	24	12	7	7	15	2,737
Hayward	14	30	64	192	50	45	52	42	147	295	246	159	22	23	16	15	26	3,492
South Hayward	3	9	11	88	9	7	5	12	119	203	93	70	16	13	4	7	6	1,616
Union City	5	13	13	133	6	12	12	13	240	333	168	112	22	16	10	15	10	2,380
Fremont	10	26	24	241	12	19	28	32	299	428	367	210	37	27	13	19	24	3,622
12th St Oakland	138	212	69	288	118	103	144	97	180	411	544	347	61	62	35	50	92	5,270
19th St Oakland	306	312	83	329	151	162	252	130	172	375	360	220	47	59	32	37	97	5,930
MacArthur	41	92	17	134	29	41	49	62	105	244	248	178	33	27	8	33	25	2,034
Oakland West	14	21	3	19	4	5	5	10	254	527	192	168	14	14	9	18	24	1,587
Rockridge	96	111	5	22	7	5	10	6	152	361	308	230	32	26	8	35	30	2,110
Orinda	52	69	16	94	7	7	5	6	265	504	165	100	10	11	5	15	13	1,852
Lafayette	51	79	10	109	10	5	6	10	303	606	186	122	10	11	7	17	19	2,147
Walnut Creek	68	190	11	172	16	12	12	15	526	918	418	267	30	22	16	26	42	3,681
Pleasant Hill	11	56	9	121	11	11	13	26	596	994	315	250	26	23	11	21	38	3,365
Concord	69	27	18	154	17	22	21	36	685	1,078	465	345	61	31	16	35	70	4,409
Ashby	10	18	5	66	19	29	42	70	30	65	77	65	12	9	6	14	8	1,074
Berkeley	90	131	74	20	95	392	613	326	126	239	424	319	57	84	76	86	122	5,858
North Berkeley	12	19	24	84	5	19	36	54	34	78	96	73	13	13	4	14	11	1,115
El Cerrito Plaza	9	22	41	403	21	9	37	59	34	70	104	54	5	4	4	14	11	1,481
El Cerrito del Norte	12	18	43	610	36	33	22	21	52	95	112	70	6	7	3	18	35	1,899
Richmond	27	36	71	307	59	58	17	10	20	49	70	53	14	9	4	16	21	1,508
Embarcadero	699	774	37	153	36	34	58	23	58	74	288	315	201	328	547	481	1,192	9,055
Montgomery	990	1,079	62	256	81	66	92	48	68	39	163	406	440	816	1,259	1,222	2,310	16,021
Powell	200	336	57	337	66	68	80	50	256	166	247	224	321	472	647	701	1,118	8,453
Civic Center	219	313	66	274	73	47	75	41	310	421	282	42	148	257	422	552	880	7,089
16th St Mission	28	60	11	54	11	7	6	14	151	366	398	141	5	45	65	129	208	2,089
24th St Mission	21	28	10	78	11	4	7	11	309	756	690	280	46	15	51	131	273	3,014
Glen Park	11	15	5	73	2	3	4	2	533	1,209	884	393	62	68	5	24	62	3,567
Balboa Park	18	46	15	77	13	10	15	15	471	1,093	1,006	529	140	140	24	9	96	4,092
Daly City	33	66	11	140	12	12	38	21	1,273	2,514	1,450	825	189	170	67	104	38	7,458
Total	3,338	4,343	1,151	5,935	1,205	1,392	1,909	1,471	8,395	15,755	11,425	7,318	2,193	2,913	3,425	3,965	7,120	129,910

Note: Trips shown on the diagonal are excursion rides.

Source: BARTD Data Acquisition System, Summary of Faregate Counts for October 21, 1976.

Table II-2 (Part 1)

STATION-TO-STATION BART RIDERSHIP, AVERAGE DAY, OCTOBER 1976, MORNING PEAK PERIOD RIDERSHIP
(7:00 a.m. to 9:00 a.m. Exit Time)

	Origin																	
Destination	Lake Merritt	Fruit-vale	Coli-seum	San Leandro	Bay Fair	Hayward	South Hayward	Union City	Fremont	12th St Oakland	19th St Oakland	Mac-Arthur	Oakland West	Rock-ridge	Orinda	La-fayette	Walnut Creek
Lake Merritt	0	30	26	40	70	55	48	47	49	1	4	19	7	9	2	4	5
Fruitvale	3	1	12	21	30	26	29	25	22	5	5	7	3	3	4	4	5
Coliseum	18	16	2	10	30	26	20	21	26	10	19	3	8	2	1	2	8
San Leandro	4	25	5	0	20	28	27	26	29	10	12	1	11	4	0	5	4
Bay Fair	2	20	10	2	1	6	10	17	42	3	5	4	1	1	0	3	1
Hayward	14	72	27	46	18	1	16	50	85	22	23	15	7	6	5	4	7
South Hayward	8	15	3	11	5	5	1	34	40	2	0	1	0	1	0	1	1
Union City	3	7	7	4	12	17	10	0	11	4	1	2	1	1	2	1	1
Fremont	9	13	12	6	16	28	14	18	2	4	6	6	2	1	1	1	1
12th St Oakland	3	61	56	110	161	94	83	106	95	0	1	14	6	33	57	71	106
19th St Oakland	6	51	42	150	218	156	131	180	154	2	0	26	8	26	83	154	172
MacArthur	1	10	3	5	17	10	13	12	17	3	3	0	2	13	7	11	22
Oakland West	4	4	8	3	12	3	6	8	11	1	1	1	0	1	2	2	5
Rockridge	0	1	2	3	4	2	1	1	2	3	1	3	3	1	44	46	60
Orinda	0	5	6	2	2	0	1	0	6	10	8	21	4	10	1	7	15
Lafayette	0	3	1	2	1	1	1	1	0	8	5	12	2	8	3	0	8
Walnut Creek	1	3	5	4	2	6	2	2	3	10	6	9	1	20	9	5	0
Pleasant Hill	0	0	1	0	1	0	1	1	2	3	5	4	2	12	17	22	16
Concord	0	5	7	3	0	2	1	1	2	10	4	6	0	13	7	10	24
Ashby	2	5	3	2	5	5	4	6	2	1	2	1	1	1	2	1	3
Berkeley	33	82	36	42	59	55	44	52	80	40	42	35	5	3	27	33	56
North Berkeley	2	4	4	3	3	1	3	3	2	6	6	8	1	2	2	2	2
El Cerrito Plaza	2	3	4	6	6	3	4	3	3	2	6	10	1	1	0	1	3
El Cerrito del Norte	1	8	3	2	5	1	0	4	3	5	2	8	0	0	1	3	2
Richmond	10	24	26	6	14	6	8	7	17	16	11	19	2	4	3	2	5
Embarcadero	50	69	25	57	133	92	101	201	218	33	34	41	191	71	212	223	350
Montgomery	130	173	47	104	231	167	141	240	278	64	62	77	355	112	287	358	545
Powell	38	65	13	32	50	38	27	35	62	29	32	44	67	44	26	40	84
Civic Center	60	115	36	56	103	64	42	66	103	48	38	66	100	80	50	62	126
16th St Mission	5	8	7	4	16	5	11	12	14	7	6	5	6	8	5	5	9
24th St Mission	1	10	1	2	3	4	3	5	8	4	4	3	3	2	1	4	6
Glen Park	0	2	2	2	2	1	0	3	1	2	1	0	2	0	1	2	2
Balboa Park	3	14	7	2	3	1	2	3	6	5	6	10	4	13	3	6	5
Daly City	7	6	4	4	5	3	1	3	3	4	4	6	2	7	3	4	12
Total	420	930	453	746	1,258	912	806	1,193	1,398	377	365	487	808	513	868	1,099	1,671

Note: Trips shown on the diagonal are excursion rides.

Source: BARTD, Data Acquisition System, Summary of Faregate Counts for October 21, 1976.

Table II-2 (Part 2)

STATION-TO-STATION BART RIDERSHIP, AVERAGE DAY, OCTOBER 1976, MORNING PEAK PERIOD RIDERSHIP
(7:00 a.m. to 9:00 a.m. Exit Time)

	Origin																	
Destination	Pleasant Hill	Concord	Ashby	Berkeley	North Berkeley	El Cerrito Plaza	El Cerrito del Norte	Richmond	Embarca-dero	Mont-gomery	Powell	Civic Center	16th St Mission	24th St Mission	Glen Park	Balboa Park	Daly City	Total
Lake Merritt	8	14	38	75	48	19	26	20	7	12	20	19	6	10	6	6	9	759
Fruitvale	7	12	13	14	7	8	14	11	3	3	5	10	5	5	2	2	3	329
Coliseum	5	14	10	9	9	4	7	7	2	3	9	10	1	5	7	1	3	328
San Leandro	3	9	9	9	5	6	8	3	3	2	5	7	3	3	3	3	2	294
Bay Fair	3	0	1	2	2	1	1	3	1	2	5	3	2	3	1	1	1	160
Hayward	5	7	14	24	16	15	23	11	4	5	11	9	4	5	3	2	5	581
South Hayward	0	3	1	2	2	1	1	2	1	2	0	1	1	2	0	1	1	149
Union City	1	5	1	4	1	3	4	0	1	2	1	1	1	0	2	2	0	113
Fremont	2	4	4	8	3	2	4	2	1	3	6	5	1	3	2	1	2	193
12th St Oakland	94	128	20	43	47	50	79	31	23	31	44	51	15	22	17	11	34	1,797
19th St Oakland	227	217	39	54	78	85	172	62	33	52	48	56	23	34	22	16	61	2,838
MacArthur	21	36	3	7	7	7	17	9	4	6	9	14	6	12	4	2	5	318
Oakland West	6	7	1	4	2	1	5	5	6	15	13	14	4	5	5	4	10	179
Rockridge	45	44	2	1	0	1	3	1	2	2	3	6	4	4	2	0	3	300
Orinda	16	28	4	3	2	3	4	2	0	3	2	2	1	2	2	5	3	180
Lafayette	8	24	5	2	2	1	0	2	2	2	3	2	2	4	0	0	2	117
Walnut Creek	12	39	1	7	5	3	3	3	2	7	6	9	3	2	3	3	4	200
Pleasant Hill	1	19	1	5	2	4	3	3	4	2	5	7	1	2	3	0	3	152
Concord	7	1	1	5	5	2	6	2	4	3	5	7	2	2	2	2	2	153
Ashby	3	7	0	0	2	5	12	6	1	3	1	3	0	0	1	1	0	91
Berkeley	45	62	21	0	30	143	292	122	7	15	20	36	8	21	32	18	42	1,638
North Berkeley	2	8	9	2	1	2	17	10	1	1	1	4	1	3	2	1	2	121
El Cerrito Plaza	1	7	11	6	3	0	6	14	0	2	0	2	1	0	2	0	0	113
El Cerrito del Norte	3	2	4	10	6	1	1	0	1	0	1	1	1	0	1	0	1	81
Richmond	13	14	28	39	23	14	6	0	1	1	4	5	5	1	2	3	10	349
Embarcadero	529	596	8	9	9	8	23	5	0	3	8	54	122	199	414	329	883	5,300
Montgomery	745	801	14	24	18	21	41	15	5	2	10	69	247	496	881	757	1,790	9,307
Powell	95	118	9	14	7	9	17	13	5	4	2	4	71	150	269	189	485	2,187
Civic Center	160	207	15	20	16	20	44	16	19	27	7	1	29	81	215	199	482	2,773
19th St Mission	17	29	1	2	2	2	0	3	3	9	13	6	0	6	33	27	85	371
24th St Mission	10	11	2	1	3	0	3	0	4	13	16	15	3	0	10	19	51	225
Glen Park	4	7	0	1	0	0	1	0	2	8	11	9	5	5	0	3	14	93
Balboa Park	6	12	5	7	3	3	6	3	15	59	173	73	29	32	8	0	43	570
Daly City	12	21	2	5	2	3	3	3	9	14	21	31	21	15	10	8	1	259
Total	2,116	2,513	297	418	368	447	852	389	176	318	488	546	628	1,134	1,966	1,616	4,402	32,618

Note: Trips shown on the diagonal are excursion rides.

Source: BARTD, Data Acquisition System, Summary of Faregate Counts for October 21, 1976.

Table II-3 (Part 1)

STATION-TO-STATION BART RIDERSHIP, AVERAGE DAY, OCTOBER 1976, EVENING PEAK PERIOD RIDERSHIP
(4:00 p.m. to 7:00 p.m. Exit Time)

	Origin																	
Destination	Lake Merritt	Fruit-vale	Coli-seum	San Leandro	Bay Fair	Hayward	South Hayward	Union City	Fremont	12th St Oakland	19th St Oakland	Mac-Arthur	Oakland West	Rock-ridge	Orinda	La-fayette	Walnut Creek
Lake Merritt	3	13	18	14	9	23	5	8	11	13	13	4	7	3	1	1	2
Fruitvale	34	3	21	29	34	62	15	12	25	71	81	9	7	6	4	5	6
Coliseum	21	12	2	7	7	26	6	4	15	55	71	11	13	6	5	4	7
San Leandro	51	29	11	1	12	32	10	7	13	113	187	17	11	6	4	2	5
Bay Fair	81	46	33	34	7	20	6	20	33	148	240	27	24	6	2	1	5
Hayward	61	46	33	59	19	3	10	33	60	98	167	19	17	5	0	2	9
South Hayward	58	37	24	61	21	21	3	13	28	71	144	16	14	3	2	1	3
Union City	71	34	31	54	43	70	25	3	27	92	179	15	22	1	0	2	3
Fremont	83	41	35	58	83	139	48	29	12	89	166	28	19	6	4	2	5
12th St Oakland	11	16	34	30	12	33	8	6	11	1	6	5	8	5	14	6	9
19th St Oakland	12	13	23	29	9	26	9	3	13	5	5	9	4	5	14	14	23
MacArthur	13	10	9	12	6	16	4	3	10	24	40	2	5	3	20	12	19
Oakland West	3	3	6	1	3	3	0	0	3	8	12	0	0	3	2	1	2
Rockridge	7	5	3	3	4	11	4	0	4	32	41	3	4	1	18	11	30
Orinda	2	2	3	1	0	4	1	0	2	55	86	15	1	30	2	7	17
Lafayette	5	5	4	4	3	6	1	2	2	77	145	14	3	38	10	3	19
Walnut Creek	7	9	10	5	3	9	0	2	5	110	187	30	6	46	20	18	7
Pleasant Hill	8	9	6	5	2	8	3	0	5	77	210	22	17	28	16	20	25
Concord	13	17	17	14	5	10	5	6	9	122	201	49	15	31	32	51	80
Ashby	23	12	10	12	4	19	1	2	7	26	47	3	2	1	3	2	3
Berkeley	69	28	28	14	9	44	8	5	18	90	97	21	5	4	5	12	17
North Berkeley	25	13	11	9	4	17	1	2	3	55	78	9	3	0	1	4	6
El Cerrito Plaza	18	12	8	14	5	14	1	5	6	58	115	12	5	1	6	2	5
El Cerrito del Norte	22	17	10	14	5	21	1	4	4	84	180	26	4	4	1	2	7
Richmond	13	14	11	5	5	8	0	4	5	38	66	17	5	1	2	3	4
Embarcadero	13	10	8	5	5	4	3	6	12	44	61	10	9	12	9	9	20
Montgomery	26	16	13	9	10	16	7	8	14	68	92	17	25	23	18	12	24
Powell	31	19	19	13	17	22	6	6	18	87	87	28	32	25	13	13	26
Civic Center	18	13	8	9	7	14	4	5	10	53	48	19	11	21	6	7	16
16th St Mission	5	8	5	4	3	6	3	2	2	20	22	6	6	5	2	1	2
24th St Mission	11	10	11	7	1	8	3	2	5	20	34	11	5	6	2	2	5
Glen Park	5	4	8	7	2	6	1	3	6	16	24	4	6	2	3	2	4
Balboa Park	6	5	3	7	2	4	1	2	3	12	17	5	4	3	6	1	4
Daly City	14	6	6	4	4	2	1	3	7	30	69	9	12	6	4	6	8
Total	843	537	482	554	365	727	204	210	408	1,962	3,219	487	331	346	51	241	427

Note: Trips shown on the diagonal are excursion rides.

Source: BARTD, Data Acquisition System, Summary of Faregate Counts for October 21, 1976.

Table II-3 (Part 2)
STATION-TO-STATION BART RIDERSHIP, AVERAGE DAY, OCTOBER 1976, EVENING PEAK PERIOD RIDERSHIP
(4:00 p.m. to 7:00 p.m. Exit Time)

	Origin																	
Destination	Pleasant Hill	Concord	Ashby	Berkeley	North Berkeley	El Cerrito Plaza	El Cerrito del Norte	Richmond	Embarca-dero	Mont-gomery	Powell	Civic Center	16th St Mission	24th St Mission	Glen Park	Balboa Park	Daly City	Total
Lake Merritt	1	4	11	56	10	4	1	12	62	127	87	71	6	4	3	9	7	624
Fruitvale	2	5	10	102	5	11	11	29	75	198	148	148	13	14	5	17	11	1,228
Coliseum	2	8	12	47	7	4	7	29	28	66	42	47	6	4	3	8	4	596
San Leandro	2	2	5	50	5	4	4	11	63	123	77	78	7	4	1	5	5	952
Bay Fair	2	5	11	73	4	4	5	20	141	271	122	122	15	5	4	2	4	1,543
Hayward	1	5	12	63	6	7	5	11	98	188	99	85	7	7	4	7	9	1,255
South Hayward	2	3	5	48	4	3	2	8	90	147	45	47	12	6	1	3	3	949
Union City	2	3	9	61	4	5	6	10	194	245	90	81	13	7	6	7	6	1,421
Fremont	3	7	6	122	4	7	8	19	228	312	156	135	23	11	3	11	9	1,911
12th St Oakland	4	12	9	70	7	10	14	21	49	122	141	106	17	12	3	9	14	835
19th St Oakland	17	15	10	98	12	14	9	24	57	116	106	71	10	8	2	8	10	803
MacArthur	8	12	3	65	5	11	8	20	54	130	98	92	15	6	1	12	7	755
Oakland West	1	1	1	6	1	2	0	2	167	357	94	97	6	3	2	5	4	799
Rockridge	12	20	1	6	2	1	1	2	77	194	129	135	10	8	1	14	8	802
Orinda	9	12	4	44	2	1	1	0	199	369	82	69	7	5	1	6	6	1,045
Lafayette	13	23	2	58	4	3	2	5	225	457	102	87	6	5	4	8	9	1,354
Walnut Creek	14	39	3	83	4	3	2	9	370	684	220	180	17	7	6	10	14	2,139
Pleasant Hill	2	12	3	66	5	2	4	14	456	787	190	179	16	15	3	9	19	2,243
Concord	27	9	7	84	7	8	6	19	541	823	250	235	38	12	6	18	26	2,793
Ashby	2	3	3	23	3	9	11	32	18	34	29	33	5	4	2	6	2	396
Berkeley	7	10	7	4	7	30	33	67	40	71	108	89	17	12	4	15	14	1,009
North Berkeley	3	3	6	33	2	7	7	24	15	42	45	40	6	2	1	4	5	486
El Cerrito Plaza	3	5	12	199	8	3	7	19	17	46	44	35	3	3	2	6	6	705
El Cerrito del Norte	3	7	16	320	11	8	5	7	33	56	49	48	3	3	1	10	5	991
Richmond	3	4	14	130	9	12	3	4	11	24	23	24	5	2	2	4	4	479
Embarcadero	11	18	5	44	5	4	2	5	11	13	52	70	12	13	12	12	18	547
Montgomery	9	19	8	67	6	5	6	6	14	9	27	70	34	45	34	52	48	857
Powell	8	26	10	98	8	9	9	10	75	53	55	61	55	54	48	73	97	1,211
Civic Center	5	15	9	77	8	3	4	5	95	116	60	9	25	34	26	53	64	877
16th St Mission	3	5	4	17	3	0	1	8	102	224	170	55	2	7	8	21	34	766
24th St Mission	4	6	3	33	4	1	2	6	215	528	346	131	15	4	11	20	35	1,507
Glen Park	2	2	2	37	0	1	2	1	428	930	512	252	22	29	3	7	20	2,353
Balboa Park	3	3	2	29	2	1	1	4	359	785	383	232	32	27	5	5	11	1,969
Daly City	5	18	2	62	2	1	2	15	1,046	1,955	813	524	88	68	25	27	12	4,856
Total	195	341	227	2,375	176	198	191	478	5,653	10,602	4,994	3,738	568	450	243	483	550	43,056

Note: Trips shown on the diagonal are excursion rides.

Source: BARTD, Data Acquisition System, Summary of Faregate Counts for October 21, 1976.

Table II-4

RIDERSHIP BETWEEN ADJACENT BART STATIONS
TYPICAL MIDWEEK DAY, OCTOBER 1976

BART Link between Stations		Ridership on Link								
		Morning Peak 7:00 a.m. - 9:00 a.m.			Evening Peak 4:00 p.m. - 7:00 p.m.			Total All Day		
A	B	A to B	B to A	Total	A to B	B to A	Total	A to B	B to A	Total
Fremont	Union City	1,396	191	1,587	396	1,899	2,295	3,439	3,579	7,018
Union City	South Hayward	2,560	275	2,835	547	3,261	3,808	5,516	5,739	11,255
South Hayward	Hayward	3,267	325	3,592	634	4,093	4,727	6,830	6,878	13,708
Hayward	Bay Fair	3,977	704	4,681	1,025	5,012	6,037	9,065	9,211	18,276
Bay Fair	San Leandro	5,108	737	5,845	1,138	6,303	7,441	10,981	11,182	22,163
San Leandro	Coliseum	5,655	832	6,487	1,351	6,914	8,265	12,177	12,448	24,625
Coliseum	Fruitvale	5,909	961	6,870	1,599	7,276	8,875	13,075	13,480	26,555
Fruitvale	Lake Merritt	6,505	956	7,461	1,690	8,058	9,748	14,340	14,830	29,170
Lake Merritt	12th Street	2,769	934	3,703	1,305	3,327	4,632	7,672	7,497	15,169
12th Street	19th Street	9,865	1,859	11,724	3,084	12,798	15,882	23,229	24,156	47,385
19th Street	MacArthur	9,983	1,530	11,513	2,739	12,645	15,384	22,490	23,105	45,595
MacArthur	Ashby	2,367	1,105	3,472	1,852	3,669	5,521	8,974	9,364	18,338
Ashby	Berkeley	2,272	1,008	3,280	1,735	3,435	5,170	8,383	8,698	17,081
Berkeley	North Berkeley	1,380	1,132	2,512	1,473	1,959	3,432	5,444	5,544	10,988
North Berkeley	El Cerrito Plaza	1,163	984	2,147	1,293	1,613	2,906	4,540	4,588	9,128
El Cerrito Plaza	El Cerrito del Norte	899	758	1,657	926	1,175	2,101	3,318	3,329	6,647
El Cerrito del Norte	Richmond	444	294	738	374	575	949	1,474	1,485	2,959
Concord	Pleasant Hill	2,465	199	2,664	386	2,730	3,116	4,317	4,381	8,698
Pleasant Hill	Walnut Creek	4,526	352	4,878	569	4,903	5,472	7,529	7,604	15,133
Walnut Creek	Lafayette	6,101	466	6,567	836	6,872	7,708	10,550	10,715	21,265
Lafayette	Orinda	7,108	521	7,629	942	8,067	9,009	12,284	12,477	24,761
Orinda	Rockridge	7,880	591	8,471	1,061	8,994	10,055	13,727	13,903	27,630
Rockridge	MacArthur	8,078	600	8,678	1,141	9,532	10,673	14,589	15,028	29,617
12th Street	Oakland West	7,288	1,121	8,409	2,106	9,849	11,955	16,950	18,242	35,192
Oakland West	Embarcadero	11,645	1,474	13,119	2,816	15,154	17,970	25,628	27,299	52,927
Embarcadero	Montgomery	8,419	3,372	11,791	4,816	12,048	16,864	23,428	25,759	49,187
Montgomery	Powell	3,498	7,440	10,938	8,869	6,356	15,225	20,787	23,384	44,171
Powell	Civic Center	2,722	8,363	11,085	10,385	4,089	14,474	20,774	20,399	41,173
Civic Center	16th Street	1,090	8,958	10,048	10,913	1,756	12,669	18,154	17,550	35,704
16th Street	24th Street	928	8,539	9,467	10,376	1,417	11,793	16,954	16,246	33,200
24th Street	Glen Park	835	7,537	8,372	9,063	1,161	10,224	14,688	14,081	28,769
Glen Park	Balboa Park	777	5,606	6,383	6,770	978	7,748	11,303	10,838	22,141
Balboa Park	Daly City	258	4,041	4,299	4,844	538	5,382	7,420	7,082	14,502
Lake Merritt	Oakland West	3,730	355	4,085	664	4,791	5,455	7,802	8,243	16,045

Note: Peak periods are defined by exit times.

Source: Peat, Marwick, Mitchell & Co. analysis of BARTD Data Acquisition System, Summary of Faregate Counts for October 21, 1976.

The most heavily traveled links of the System are the transbay link between Oakland West and Embarcadero (52,900 trips daily) and the link between 12th and 19th Streets in Oakland which carries both Richmond and Concord Line riders (47,400 trips daily).

Time-of-Day Distribution. Figures II-2 through II-7 show the distribution of BART ridership over the hours of the day for the following groups of stations:

Figure II-2
Fremont Line Stations

Fruitvale
Coliseum
San Leandro
Bay Fair
Hayward
Union City
Fremont

Figure II-3
Central Oakland Stations

Lake Merritt
12th Street Oakland
19th Street Oakland
MacArthur
Rockridge
Oakland West

Figure II-4
Concord Line Stations

Orinda
Lafayette
Walnut Creek
Pleasant Hill
Concord

Figure II-5
Richmond Line Stations

Ashby
Berkeley
North Berkeley
El Cerrito Plaza
El Cerrito del Norte
Richmond

Figure II-6
Central San Francisco Stations

Embarcadero
Montgomery
Powell
Civic Center

Figure II-7
Outer San Francisco Stations

16th Street Mission
24th Street Mission
Glen Park
Balboa Park
Daly City

The figures show the number of passengers exiting from these groups of stations during each hour from 6:00 a.m. through 12:00 midnight for a typical midweek day in October 1976. The data shown are faregate counts recorded by the BART DAS.

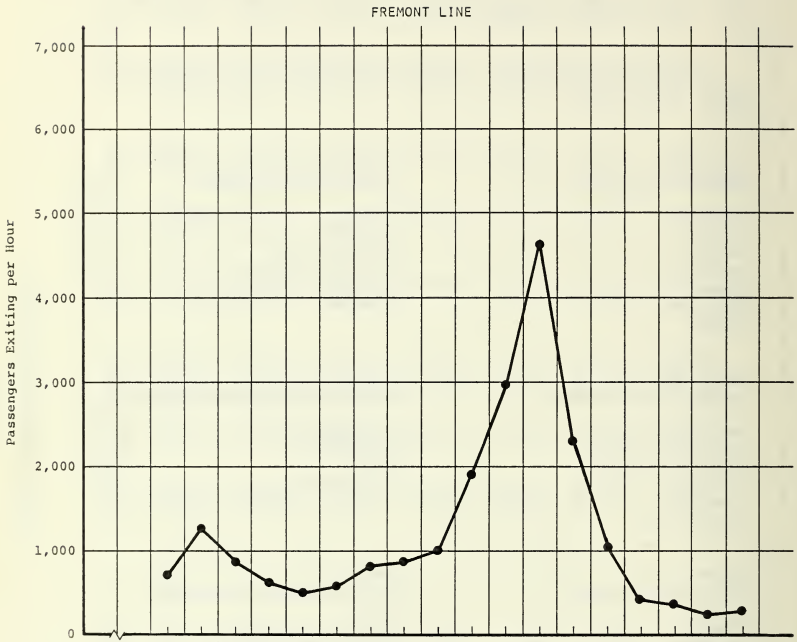

FIGURE II-2

TIME-OF-DAY DISTRIBUTION OF BART RIDERSHIP, 8 FREMONT LINE STATIONS
(TYPICAL MIDWEEK DAY, OCTOBER 1976)

Source: BARTD, Data Acquistion System Summary of Faregate Counts for October 21, 1976.

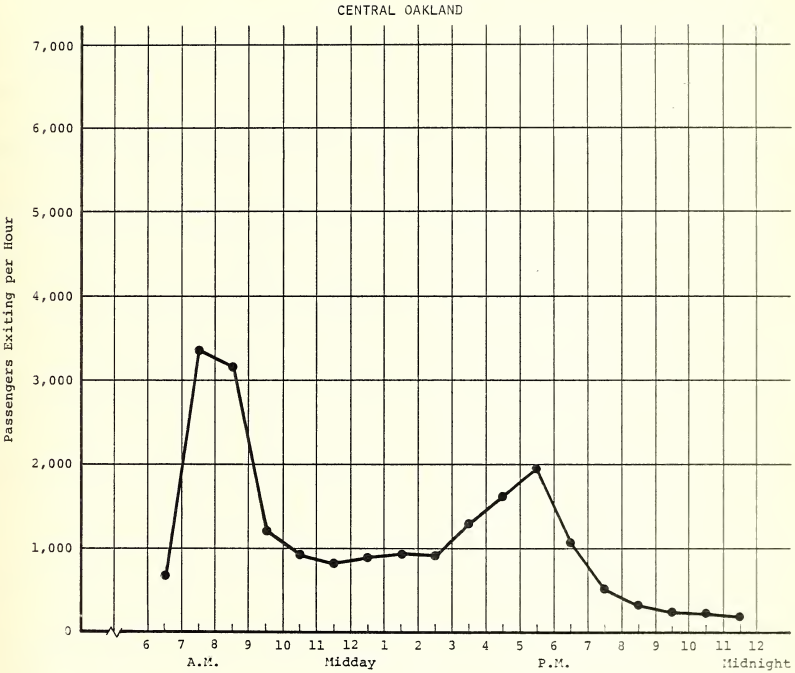

FIGURE II-3

TIME-OF-DAY DISTRIBUTION OF BART RIDERSHIP, 6 CENTRAL OAKLAND STATIONS
(TYPICAL MIDWEEK DAY, OCTOBER 1976)

Source: BARTD, Data Acquistion System Summary of Faregate Counts for October 21, 1976.

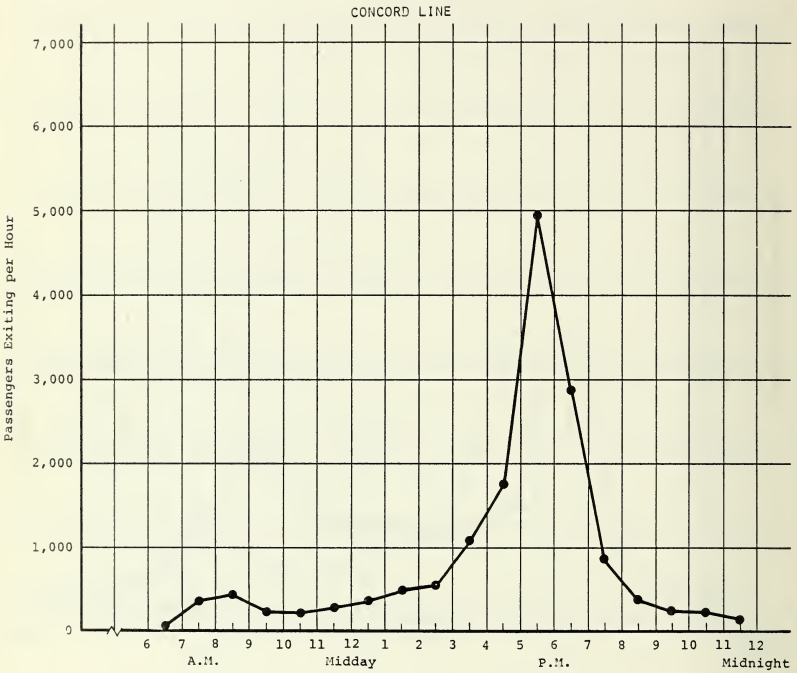

FIGURE II-4

TIME-OF-DAY DISTRIBUTION OF BART RIDERSHIP, 5 CONCORD LINE STATIONS
(TYPICAL MIDWEEK DAY, OCTOBER 1976)

Source: BARTD, Data Acquistion System Summary of Faregate Counts for October 21, 1976.

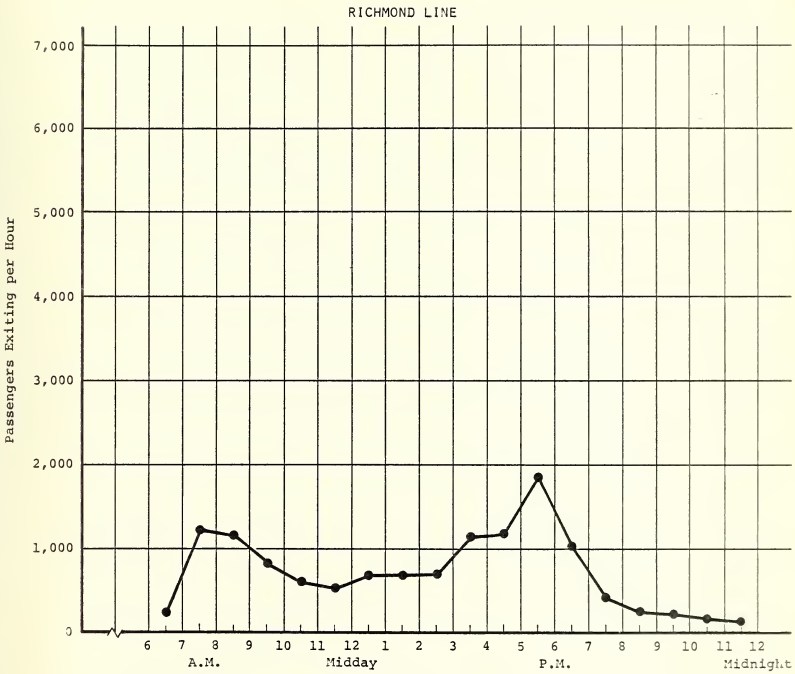

FIGURE II-5

TIME-OF-DAY DISTRIBUTION OF BART RIDERSHIP, 6 RICHMOND LINE STATIONS
(TYPICAL MIDWEEK DAY, OCTOBER 1976)

Source: BARTD, Data Acquistion System Summary of Faregate Counts for October 21, 1976.

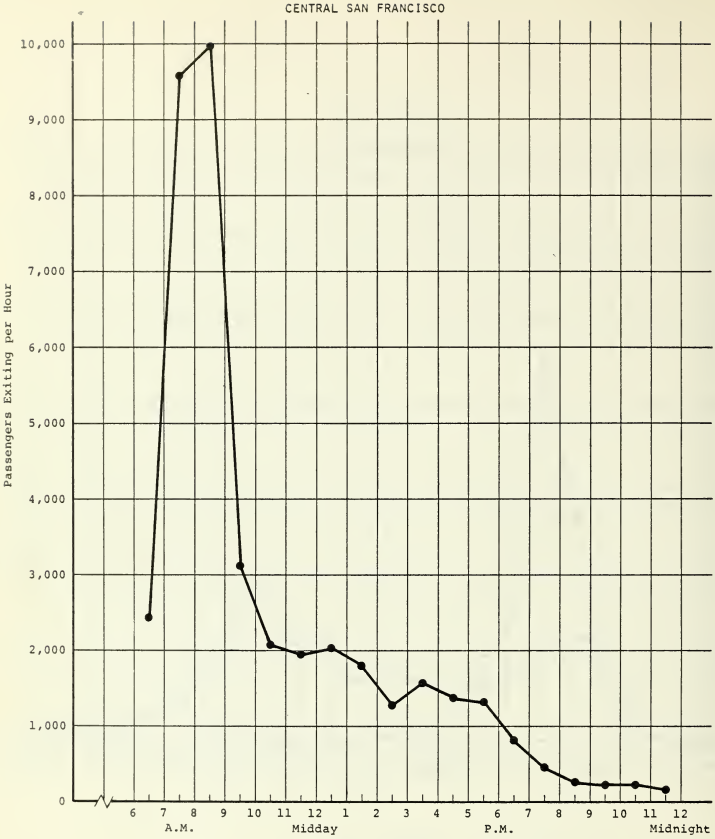

FIGURE II-6

TIME-OF-DAY DISTRIBUTION OF BART RIDERSHIP, 4 CENTRAL SAN FRANCISCO STATIONS
(TYPICAL MIDWEEK DAY, OCTOBER 1976)

Source: BARTD, Data Acquistion System Summary of Faregate Counts for October 21, 1976.

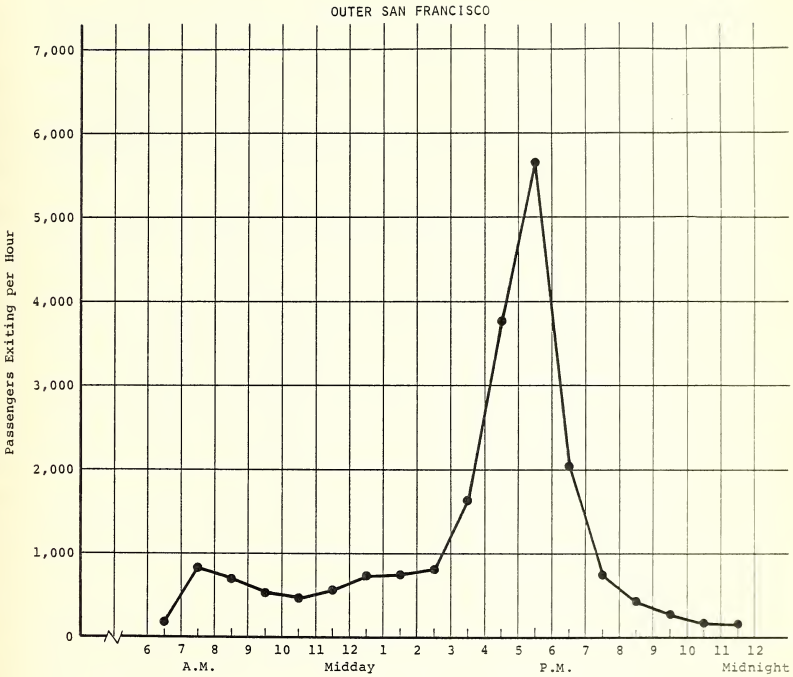

FIGURE II-7

TIME-OF-DAY DISTRIBUTION OF BART RIDERSHIP, 5 OUTER SAN FRANCISCO STATIONS
(TYPICAL MIDWEEK DAY, OCTOBER 1976)

Source: BARTD, Data Acquistion System Summary of Faregate Counts for October 21, 1976.

Again, the figures show the peaked nature of BART ridership overall, although the lines differ markedly. The Central San Francisco stations (Figure II-6) and Central Oakland stations (Figure II-3) have their highest exiting passenger volumes during the morning peak--reflecting the predominance of BART stations serving workplace destinations. In contrast, the Fremont Line stations (Figure II-2), Concord Line stations (Figure II-4), and Outer San Francisco (Figure II-7) have their highest exiting passenger volumes in the evening--reflecting the predominance of BART stations serving residential areas. On the Richmond Line, peak ridership is lower relative to off-peak and more evenly distributed between morning and evening.

These ridership profiles are summarized numerically in the following tabulation, which compares the number of BART riders exiting stations between the peak hours of 7:00 a.m. to 9:00 a.m. and 4:00 p.m. to 7:00 p.m. with all-day ridership.

Station Group	Riders Exiting in Peak Periods A.M.	P.M.	Riders Exiting All Day	Percent Exiting in Peak Periods A.M.	P.M.
Fremont Line	2,147	9,855	21,271	10%	46%
Central Oakland	6,191	4,618	19,864	31%	23%
Concord Line	802	9,574	15,574	5%	61%
Richmond Line	2,393	4,066	13,154	18%	31%
Central San Francisco	19,567	3,492	40,749	48%	9%
Outer San Francisco	1,518	11,451	20,426	7%	56%
Total	32,618	43,056	131,038[a]	25%	33%

a. The slight difference between this total (131,038) and the total all-day ridership shown in Table II-1 (129,910) occurs because the figures for hourly ridership given by the DAS summary do not sum exactly to the total.

Previous Mode of BART Travelers

Table II-5 shows the mode of travel previously used by BART travelers surveyed in each of the four years since BART started service. Results for East Bay, West Bay, and transbay travel are shown separately, as is the total for all BART travel.

Each successive survey shows an increasing percentage of travelers who "did not make the trip before BART." Conversely, the percentage of BART riders who made the same trip before BART becomes smaller as the interval between the start date of BART service and the survey date increases. Changes in home and work locations account for most of the trips that travelers report they did not make previously.

The 1976 BART Passenger Profile Survey results show that 28% of respondents reported they did not make the trip before BART. Of these, 21% did not make the trip because they "did not live where they do now" or "did not work where they do now." The remaining 7% are trips not made before for other reasons, including "did not have convenient transportation available." These 7% of trips can be considered an estimate of the number of new trips being made on BART, i.e., trips which would probably not be made at all if BART were not available.

As the percentage of BART travelers who never made the trip before increases, estimating the hypothetical distribution of ridership among the other modes "without BART" becomes more uncertain, because information is unavailable on the alternative mode of people who did not travel previously. However, taking into account this uncertainty, the results of the four surveys shown in Table II-5 appear to be generally consistent.

Considering only the survey results for East Bay travelers who made the trip before BART, gives the estimate that about 30% of BART's ridership is drawn from bus, and about 70% from automobile. In the West Bay, the picture is very different, with perhaps 65% of BART's ridership coming from bus and only 35% from automobile.

The survey of transbay travel conducted immediately after BART transbay service began in 1974 shows that, for trips made before BART, about 60% were diverted from bus and 40% from automobile. The more recent surveys (1975 and 1976) suggest that, as time goes by, BART draws more transbay riders from automobiles than from buses. (Omitting those who did not travel previously, the alternative mode distribution of BART riders is shown in the 1976 survey as about 45% from bus and 55% from automobile.)

It is logical that the percentage of transbay BART riders who previously rode the bus should be reduced between the 1974 and 1976 surveys. This is because a high proportion of the bus riders that switched to BART

Table II-5

PREVIOUS MODE OF BART TRAVELERS

	Survey Date			
	1973[a]	1974[b]	1975[c]	1976[d]
East Bay BART Travel				
Bus	27%	24%	23%	18%
Automobile[e]	56	50	46	48
Other Modes	3	2	2	2
Did Not Make Trip Before	14	24	29	32
Total	100%	100%	100%	100%
(Actual Number of Trips)	(24,900)	(40,700)	(37,600)	(40,700)
West Bay BART Travel				
Bus or Streetcar	n.a.	55%	52%	51%
Automobile[e]	n.a.	30	26	26
Other Modes	n.a.	4	4	2
Did Not Make Trip Before	n.a.	11	18	21
Total		100%	100%	100%
(Actual Number of Trips)		(25,400)	(27,300)	(32,000)
Transbay BART Travel				
Bus	n.a.	54%	46%	30%
Automobile[e]	n.a.	35	33	41
Did Not Make Trip Before	n.a.	11	21	29
Total		100%	100%	100%
(Actual Number of Trips)		(51,900)	(52,700)	(50,700)
Total for All BART Travel				
Bus or Streetcar	27%	44%	38%	31%
Automobile[e]	56	39	36	39
Other Modes	3	2	2	2
Did Not Make Trip Before	14	15	24	28
Total	100%	100%	100%	100%
(Actual Number of Trips)	(24,900)	(118,000)	(117,600)	(123,400)

n.a. = not applicable (until November 1973, BART only provided East Bay service).

See footnotes on following page.

Table II-5 (cont.)
PREVIOUS MODE OF BART TRAVELERS

a. Source: BARTD Office of Research, May 1973 BART Passenger Profile Survey. Data were not weighted to account for differential response rates by time of day or questionnaire handout location. Actual numbers of trips are average daily one-way trips for May 1973.

b. Source for East Bay and West Bay travel: BARTD Office of Research, May 1974 BART Passenger Profile Survey. Data were not weighted to account for differential response rates by time of day or location. Actual numbers of trips are average daily one-way trips for May 1974.

Source for transbay travel: BART Impact Program, October 1974 Survey of Transbay BART Travel. Data were weighted to account for differential response rates by time of day and location. Actual number of trips is average daily one-way trips for October 1974.

c. Source: BARTD Office of Research, May 1975 BART Passenger Profile Survey. Data were weighted to account for differential response rates by time of day. Actual numbers of trips are average daily one-way trips for May 1975.

d. Source: BARTD Office of Research, May 1976 BART Passenger Profile Survey. Data were weighted to account for differential response rates by time of day and location; also to account for differential response rates by racial/ethnic category. Estimates for all BART's operating day (6:00 a.m. to 12 midnight) were made from the data for the period of the survey (6:00 a.m. to 3:00 p.m. and 7:00 p.m. to 12 midnight). Actual numbers of trips are average daily one-way trips for March 1976.

e. Automobile includes motorbike or motorcycle.

did so immediately, since initially, their automobiles could provide improved service when BART's introduction reduced traffic congestion on the Bay Bridge. However, since then bus service has remained constant (or improved), while automobile service levels have declined--lessening the incentive for bus riders to switch and increasing the incentive for automobile travelers to switch to BART.

But the size of the apparent change in the previous mode distributions is puzzling given the relatively small changes in overall ridership by bus and BART between the 1974 and 1976 surveys. Some part of the differences in the results of the two surveys may be explained by slight changes in survey question wording.* Movement of travelers among the modes--for example from BART back to bus--may also be a factor. However, the dominant reason is probably the uncertainty associated with the 1976 survey estimates. As noted above, this uncertainty derives from the greatly increased number of survey respondents who did not travel previously.

Because of this uncertainty, the results of the (1974) survey conducted immediately after transbay service began probably gives a better estimate of the previous mode distribution of BART riders than the 1976 survey. This is supported by the fact, documented in Chapter III, that the 1974 survey estimate of the number of BART trips previously made by bus (about 14,000 bus trips per day in each direction) is the same as the observed reduction in transbay bus ridership at the time BART started service.

Taking the survey results for East Bay, West Bay, and transbay travel together suggests that, without BART, something like half of current BART trips probably would be made by bus and half by automobile. (This assumes, of course, that bus service levels, traffic congestion, and the relative costs of travel by bus and automobile would be at approximately their pre-BART levels.)

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*In the 1974 transbay survey, travelers were asked "How did you most often make the type of trip you are making on BART today before BART was running?" Possible responses were "bus," "drove car alone," and "car pool." In 1976 travelers were asked "Did you ever make the trip you are now making before you used BART?" If yes, "How did you make it then?" Possible responses were "bus," "drove alone in car, truck, or van," and "drove or rode with others."

III. CHANGES IN BUS RIDERSHIP AND SERVICE

This chapter discusses BART's impacts on the other major transit systems in the BART service area: MUNI, AC Transit, and Greyhound.* A description of the services provided by each is given in Chapter I.

Areawide Transit Ridership

Table III-1 and Figure III-1 show reported weekday ridership on BART, MUNI, AC Transit, and Greyhound. Although effectively outside BART's potential service area, ridership on Golden Gate Transit, the other major transit operator in the BART counties, is also shown. Table III-1 gives the data used to construct Figure III-1.

In October 1976, average weekday ridership on all services of MUNI was about 345,000 trips (48% of the total carried by all the services shown). Ridership on all of AC Transit's services was about 210,000 trips per weekday (29% of the total); Golden Gate Transit carried about 30,000 trips per weekday (4%); and Greyhound carried about 2,000 (1%). BART's average daily ridership in October 1976 was about 132,000 (18% of total transit ridership on the systems shown in Figure III-1).

The figure shows that since the start of operations in September 1972, BART has captured a significant share of total areawide transit ridership, with the share increasing appreciably when service began on each of the BART lines. However, even though a large number of riders diverted to BART, BART's impacts on MUNI's and AC Transit's total ridership are not obvious. On MUNI, ridership in 1976 averaged 350,000 trips per weekday, about 5% below the 367,000 average for 1972. On the entire AC Transit system, ridership increased 11% from an average of 171,000 trips per weekday in 1972 (January through October) to 189,000 trips per weekday for the same period in 1976. Only Greyhound shows an obvious BART-related drop in ridership after transbay BART service began--dropping from an average of 11,800 trips per weekday in January 1974 to 3,400 trips per day in January 1975. Overall, during the period January 1972 through October 1976, total ridership on all the transit systems shown increased from an average of 581,000 trips per weekday to 718,000 trips per weekday; an increase of 24%.

The aggregate transit ridership data for MUNI and AC Transit presented in Figure III-1 reveal little about the nature of BART's impacts largely because trips using more than one system during a single journey are double counted (that is, a single trip using both AC Transit and BART is counted as a trip on each). The aggregate data also mask the different impacts BART has had on different services and lines of the systems.

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*Greyhound commuter services between central Contra Costa County and San Francisco only.

Table III-1 (Part 1)

HISTORICAL WEEKDAY TRANSIT RIDERSHIP IN THE SAN FRANCISCO BAY AREA
1972-1974

Year	Month	One-Way Transit Trips per Weekday					
		San Francisco MUNI[a]	AC Transit[b]	Greyhound[c]	Golden Gate Transit[d]	BART[e]	Total
1972	January	380,078	174,919	11,878	14,444	--	581,319
	February		178,116	11,968	14,709	--	584,871
	March		175,231	12,058	15,768	--	583,135
	April	375,291	181,628	12,148	16,394	--	585,461
	May		179,891	12,004	17,509	--	584,695
	June		164,789	11,860	17,267	--	569,207
	July	366,027	150,487	11,716	19,398	--	547,628
	August		146,842	11,868	18,781	--	543,518
	September		173,483	12,020	20,198	16,930[f]	588,658
	October	348,168	182,464	12,172	18,302	16,065	577,171
	November		180,777	12,456	20,572	13,380	575,353
	December		162,326	12,740	20,111	14,140	557,485
1973	January	316,926	172,192	13,024	19,234	12,245	533,624
	February		179,292	12,962	21,422	26,820[g]	557,425
	March		181,877	12,902	22,079	24,940	558,727
	April	322,937	179,914	12,840	21,896	26,360	563,947
	May		185,458	12,110	22,539	24,900	567,944
	June		172,876	11,380	23,484	36,650[h]	567,327
	July	374,392	158,022	10,650	23,704	--[i]	566,768
	August		153,454	11,116	22,758	33,730	595,450
	September		183,709	11,580	26,087	32,600	638,368
	October	366,837	190,932	12,046	26,427	35,500	631,742
	November		185,712	11,960	25,167	68,000[j]	657,676
	December		175,325	11,872	25,574	69,800	649,408
1974	January	335,739	187,996	11,786	26,511	65,600	627,632
	February		202,302	11,974	29,038	70,400	649,452
	March		209,849	12,164	30,386	80,400	668,538
	April	362,281	191,672	12,352	27,804	72,400	666,509
	May		199,414	12,058	27,946	66,100	667,799
	June		193,789	12,426	26,636	68,000	663,132
	July	363,341	--[k]	13,958	26,085	69,500	472,884
	August		--[k]	13,958	25,671	73,600	476,570
	September		172,234	7,100	26,777	91,336[l]	660,788
	October	370,675	179,114	4,600	28,387	119,526	702,302
	November		177,416	4,420	27,716	122,937	703,164
	December		185,118	3,400	26,842	126,540	712,575

Table III-1 (Part 2)

HISTORICAL WEEKDAY TRANSIT RIDERSHIP IN THE SAN FRANCISCO BAY AREA
1975-1976

Year	Month	One-Way Transit Trips per Weekday					
		San Francisco MUNI[a]	AC Transit[b]	Greyhound[c]	Golden Gate Transit[d]	BART[e]	Tota
1975	January		187,755	3,420	28,123	118,370	696,5
	February	358,831	190,301	3,382	29,195	114,348	696,0
	March		192,424	3,386	29,547	115,995	700,1
	April		196,518	3,160	29,670	115,702	709,4
	May	364,448	192,312	2,934	30,058	117,514	707,2
	June		157,138	2,665[m]	28,674	121,337	674,2
	July		146,919	2,397[m]	28,854	124,314	678,9
	August	376,453	141,181	2,129[m]	29,027	125,648	674,4
	September		180,694	1,860	31,083	121,804	711,8
	October		194,030	1,814	30,574	125,171	730,5
	November	378,984	193,876	1,846	31,802	121,428[n]	727,9
	December		180,964	1,680	29,380	128,130[o]	719,1
1976	January		196,816	1,761[m]	30,981	122,736	709,5
	February	357,261	198,333	1,842	32,177	123,614	713,2
	March		201,284	1,820[m]	31,699	123,399	715,4
	April	--P	188,735	1,798[m]	31,093[q]	145,072	366,7
	May	344,182	199,823	1,776[m]	--q	136,172	681,9
	June		176,023	1,754[m]	24,703[q]	131,466	678,1
	July		166,473	1,732[m]	27,664	130,426	681,4
	August	355,180	163,058	1,710[m]	27,306	130,602	677,8
	September		194,650	1,688[m]	29,932	131,601	712,7
	October	344,828	209,855	1,666[m]	30,346	131,602	718,1

See footnotes on following page.

Table III-1 (Parts 1 and 2 cont.)
HISTORICAL WEEKDAY TRANSIT RIDERSHIP IN THE
SAN FRANCISCO BAY AREA

a. Source: San Francisco Municipal Railway, quarterly patronage reports. Weekday ridership is assumed to be 0.79 of total weekly ridership, as determined from the BART Impact Program, May 1975, areawide telephone survey.
b. Source: AC Transit District, reports of daily unaudited revenue, mileage, and passengers excluding mail carrier and charter revenues, also refunds, etc. (Form 34). Average for all weekdays excluding public holidays. Includes special suburban BART feeder and BART express services. Effective July 1975, Form 34 counts include nonrevenue ridership such as mail carriers and relatives of employees. Numbers shown in the table are adjusted to exclude these nonrevenue riders.
c. Source: Western Greyhound Lines. Counts of Contra Costa County a.m. commute service westbound. Data provided by Greyhound, the California State Public Utilities Commission (PUC), and University of California ITS semiannual survey counts. The ITS counts are used as a control base since they also include Vallejo service. Ridership for other months of the year is estimated from the PUC counts by adjusting for ridership on the Vallejo service based on the ITS counts.
d. Source: Golden Gate Bridge Highway and Transportation District patronage counts.
e. Source: Bay Area Rapid Transit District monthly patronage reports.
f. BART Fremont Line service began September 11, 1972.
g. BART Richmond Line service began January 29, 1973.
h. BART Concord Line service began May 21, 1973.
i. BART strike.
j. BART Daly City Line service began November 5, 1973.
k. AC Transit strike.
l. BART transbay service began September 16, 1974.
m. Estimated by interpolation (data not available).
n. BART fare increase effective November 3, 1975.
o. BART evening service began effective November 28, 1975.
p. MUNI strike, April 1 to May 7, 1976.
q. Golden Gate Transit strike, April 12 to June 14, 1976.

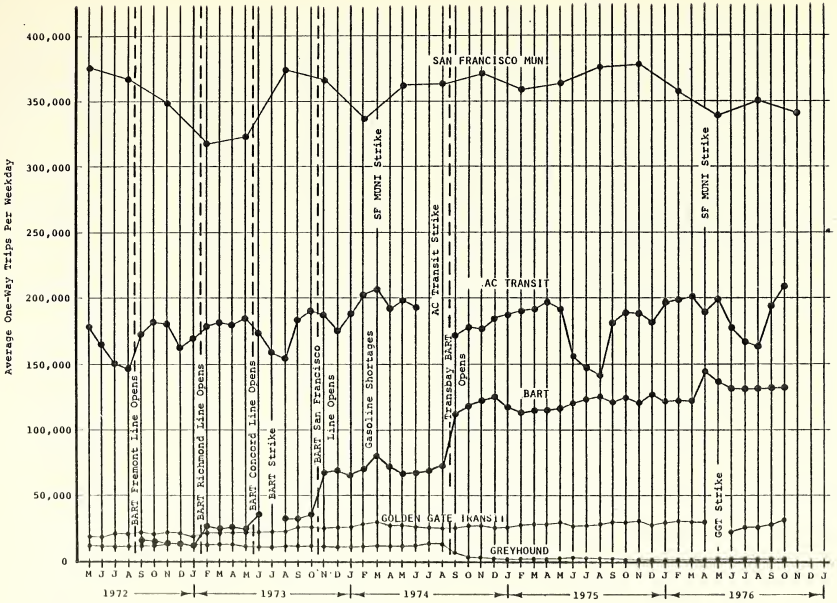

FIGURE III-1

RIDERSHIP ON BART, MUNI, AC TRANSIT, GOLDEN GATE TRANSIT, AND GREYHOUND

MAY 1972 - OCTOBER 1976

Note: Ridership on AC Transit and MUNI includes trips to and from BART.

Sources:
- BARTD Office of Research, Monthly BART Patronage Reports.
- AC Transit District, Daily Passenger Counts.
- San Francisco MUNI, Quarterly Patronage Reports.
- Golden Gate Transit District, Monthly Patronage Counts.
- Greyhound Lines, Inc., Contra Costa Service Passenger Counts.

The remaining sections of this chapter analyze changes in ridership and service on each of the MUNI, AC Transit, and Greyhound systems in more detail.

San Francisco MUNI Ridership

The MUNI ridership data displayed in Figure III-1 do not indicate any sustained pattern of change over the period; nor do they suggest a significant BART impact when service began on the line between Daly City and downtown San Francisco in November 1973. If anything, there appears to be an overall downward trend in ridership, but this is contradicted by the trend in the data for the first quarter in each year. In the first quarter of 1973, MUNI ridership averaged about 316,900 trips per weekday. By the first quarter of 1974 (following the start of BART Daly City Line service), MUNI ridership had increased to 335,800 trips per weekday, rising to about 358,800 in the first quarter of 1975 following the start of transbay BART service, which effectively doubled BART's service frequency in San Francisco, and decreasing slightly to 357,300 in the first quarter of 1976.

Table III-2 shows the distribution of quarterly MUNI ridership among its streetcar, cable car, trolley bus, and motor bus services. In the fourth quarter of 1976, the distribution of weekday ridership (344,800 trips) was: streetcar, 48,800 trips (14%); cable car, 37,000 trips (11%); trolley bus, 111,800 trips (32%); and motor bus, 148,000 trips (43%).* The average number of travelers using the discount ticket to transfer from MUNI to BART is about 3,700 trips per weekday.

Diversion of Ridership from MUNI to BART. No BART impacts can be detected from the aggregate ridership figures given in Table III-2; and comprehensive time-series data on ridership at a more detailed level are not available for the MUNI system. To assess the impact of BART on MUNI's ridership, it is, therefore, necessary to rely heavily on BART passenger survey data to estimate how the people currently riding BART would make the trip if BART were not available.

As given in Table II-5, the most recent survey of BART's ridership shows that 51% of current West Bay BART riders previously used MUNI for their trip, and a further 21% did not make the trip before. Of these 21%, about 4% are estimated as "new" trips, i.e., trips which would probably

*Average weekday ridership was estimated from the quarterly totals given in Table III-2 by assuming that 79% of weekly bus ridership occurs on weekdays. This figure was estimated from the results of the BART Impact Program May 1975 Areawide Travel Survey (which included riders on AC Transit East Bay and transbay buses as well as MUNI).

Table III-2

DISTRIBUTION OF SAN FRANCISCO MUNI RIDERSHIP AMONG SERVICES

Year	Quarter	Total One-Way Transit Trips per Quarter					Transfers
		Street Cars	Cable Cars	Trolley Coaches	Motor Coaches	Total[a]	MUNI to BART
1972	1	4,450,173	1,725,634	9,020,692	15,113,529	30,310,028	--
	2	4,265,338	1,727,874	9,049,056	15,361,060	30,403,328	--
	3	4,280,650	1,699,837	8,684,305	14,524,696	29,189,488	--
	4	4,004,402	1,605,979	8,128,300	13,585,887	27,324,568	--
1973	1	3,761,377	1,492,998	8,096,218	11,923,266	25,273,859	--
	2	3,821,587	1,602,481	7,774,214	12,963,725	26,162,007	--
	3	4,361,540	1,838,976	8,869,639	14,786,521	29,856,676	--
	4	4,273,334	1,798,426	8,690,588	14,491,693	29,254,041[b]	--
1974	1	3,850,276	1,619,136	7,830,812	13,048,928	26,349,152[c]	--
	2	4,288,261	1,803,483	8,720,711	14,536,919	29,349,374	--
	3	4,302,240	1,811,918	8,746,772	14,574,223	29,435,203	--
	4	4,319,827	1,816,664	8,779,939	14,643,722	29,560,152	--
1975	1	4,116,481	1,729,416	8,368,476	13,947,026	28,161,399	--
	2	4,314,839	1,813,651	8,772,194	14,624,221	29,524,905	276,706
	3	3,976,968	4,099,563[d]	9,722,267	12,698,629	30,497,427	291,675
	4	4,122,067	3,402,059	9,498,321	12,720,614	29,743,061	335,828
1976	1	3,941,989	3,107,196	8,874,696	12,566,544	28,490,425	326,631
	2[e]	2,178,716	2,069,119	4,770,541	7,101,546	16,119,922	147,972
	3	3,955,533	3,546,204	8,132,229	13,140,083	28,774,049	265,090
	4	3,830,394	2,951,607	8,918,322	11,798,628	27,498,951	291,815

a. Total excludes transfers between lines.
b. BART San Francisco-Daly City service began November 5, 1973.
c. San Francisco city workers' strike shut down MUNI, March 1974.
d. MUNI adopted a revised method of estimating cable car ridership from the third quarter of 1975. Earlier estimates understate ridership.
e. San Francisco MUNI strike April 1, 1976, to May 7, 1976.

Source: San Francisco MUNI, Quarterly Recapitulation of Passenger Traffic.

not be made if BART were not available.* It seems reasonable to assume that, without BART, the remaining 17% would be split between bus (or another MUNI service) and automobile (or other mode) in the same proportions (0.64 to 0.36) as the split of trips that actually were made before BART. This assumption gives the result that, if BART were not available, 62% of the 36,900 West Bay trips** currently made on BART, or 22,800 trips in total, would be made on the MUNI system. (These 22,800 trips represent about 7% of MUNI's current total weekday ridership of 344,800.)***

Use of MUNI To Get to and from BART. The diversion of trips from MUNI to BART is offset by trips now made on MUNI to get to or from West Bay BART stations. Table III-3 presents estimates of the number of trips made to and from BART in San Francisco according to the mode of travel used before BART. Two groups of BART trips are shown: trips made entirely within the West Bay (which have two access trips in the West Bay associated with every BART trip) and transbay BART trips (which have a San Francisco access trip at only one end of the trip).

Numbers in the table marked with a solid circle represent completely new access trips on MUNI, totaling 8,800 trips daily. The numbers marked with a hollow circle represent estimates of access trips on MUNI which substitute for "line-haul" trips previously made on MUNI. These total 12,700 trips daily. The number marked with a square represents a loss of access trips on MUNI (4,500 trips). The table thus portrays a net gain of 17,000 "access" trips daily using MUNI to get to or from BART (8,800 plus 12,700 minus 4,500).

Net BART Impacts on MUNI System Ridership. As estimated above, the diversion of trips from MUNI to BART resulted in a reduction of 22,800 "line-haul" trips on the MUNI system. Table III-3 shows that this loss in line-haul trips is largely offset by 17,000 "access" trips using MUNI to get to and from BART. The access trips are generally shorter than the line-haul trips, are less downtown-oriented, and produce a lower average farebox revenue per trip; so the two trip estimates are not strictly comparable. But taking the two estimates together gives a net loss of 5,800 trips daily on the MUNI system. This represents less than 2% of the current total weekday ridership on the entire MUNI system (344,800 trips).

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*The May 1976 BART Passenger Profile Survey shows that for all BART trips made within the West Bay 21.0% were not made before BART began service; 17.5% because the respondent "didn't live here" or "didn't work here"; and 3.5% for other reasons, including "did not have convenient transportation available."

**Average daily West Bay BART ridership, October 1976.

***Throughout the text of this chapter, percentages are given to the nearest percent and numbers of trips are given to the nearest 100 trips. Rounding errors may cause minor discrepancies between the two.

Table III-3

USE OF MUNI TO GET TO AND FROM BART

	Number of Trips to and from BART Using MUNI Bus or Streetcar	Walking, Automobile, or Other Mode	Total Access Trips[a]
Trips within San Francisco			
New trips	400 ●	2,200	2,600[b]
Previously used MUNI bus or streetcar	8,100 ○	37,500	45,600[c,d]
Previously walked, used automobile or other mode	3,500 ●	22,100	25,600[c]
Subtotal, trips within San Francisco	12,000[e]	61,800	73,800
Transbay Trips			
New trips	800 ●	3,400	4,200[f]
Previously used transbay bus and used MUNI to get to or from transbay bus terminal	4,600[g] ○	4,500[h] ■	9,100[i]
Previously used transbay bus and walked or used some other mode to get to or from bus terminal	200[g] ●	18,500[h]	18,700[i]
Previously used automobile or some other mode	3,900 ●	17,200	21,100[i]
Subtotal, transbay trips	9,500	43,600	53,100
Total trips to and from BART	21,500	105,400	126,900

● : Access trips representing a gain to MUNI.
○ : Access trips substituting for pre-BART MUNI trips.
■ : Access trips representing a loss to MUNI.

See footnotes on following pages.

Table III-3 (cont.)
USE OF MUNI TO GET TO AND FROM BART

a. All numbers are daily access trips to and from BART, with a (single) origin-to-destination trip on BART counting as two access trips--one from the origin to BART and one from BART to the destination. Thus, the total shown for access trips within San Francisco (73,800) is two times average daily West Bay BART ridership. However, a West Bay access trip is made at only one end of a transbay BART trip. Therefore, the total shown for the West Bay access portion of transbay trips (53,100) is equal to average daily transbay BART ridership. Both the 73,800- and 53,100-trip control totals are average daily trips for October 1976.
b. The number of new trips (i.e., trips which would probably not be made without BART) is estimated as 3.5% of total BART trips. The May 1976 BART Passenger Profile Survey (1976 PPS) shows that 21.0% of respondents did not make their trip before BART started service. However, 17.5% of these are accounted for by changes in residence or workplace. The remaining 3.5% began making the trip for other reasons, including the availability of convenient transportation. The total estimated number of new trips (2,600) is distributed between the two access modes in the same proportions as the total of trips which were made previously.
c. The distribution of trips among previous modes and current access modes is estimated using the 1976 PPS. Trips shown are estimates of all trips made during the day. These estimates were made from the results of the survey (which was conducted only from 6:00 a.m. to 3:00 p.m. and 7:00 p.m. to midnight) by assuming that the characteristics of trips made in the afternoon peak (3:00 p.m. to 7:00 p.m.) are the same as those of trips made in the morning peak except that afternoon access and egress trips are the "mirror image" of morning egress and access trips, respectively.
d. Previous trips in which a transfer was made between different MUNI vehicles are counted as single trips.
e. A relatively small number of trips made to and from BART on other bus systems (principally SamTrans service at the Daly City Station) are included.
f. The number of new trips is estimated as 8.0% of the total. The 1976 PPS shows that 8.0% of BART transbay trips were made for the first time after BART began for reasons other than a change of residence or workplace. The total estimated number of new transbay trips (4,200) is distributed between the two access modes in the same proportions as the total of trips which were made previously.
g. Among previous transbay bus users who now use BART, very few people who used to walk to their destination from the transbay bus terminal now use MUNI from BART. These people are estimated at 5% of total previous transbay bus users who now use transbay BART (4,800).
h. According to the BART Impact Program October 1974 Survey of Transbay Bus Travel, 19.6% of all transbay bus riders use a MUNI bus to get to or from the transbay bus terminal in San Francisco, and 80.4% walk or use some other mode. The same distribution is assumed within the total of 23,000 transbay BART trips which previously used transbay bus and now walk or use some other mode to get to and from BART in San Francisco.

Table III-3 (cont.)
USE OF MUNI TO GET TO AND FROM BART

i. The total of trips previously made by transbay bus (27,800) are estimated using the analysis of changes in transbay bus ridership presented later in this chapter. The implied percentage of transbay trips previously made by bus is 52%. The (residual) number of trips, estimated as previously made by automobile or other modes (21,100), represents 40% of the total. These percentages agree closely with the results of the BART Impact Program October 1974 Survey of Transbay BART Travel. (See Table II-5.)

The distribution of the totals between MUNI and other access modes is estimated from the 1976 PPS. In estimating the access mode distribution for BART trips during the entire day, the access mode distribution of afternoon (3:00 p.m. to 7:00 p.m.) trips is assumed to be the "mirror image" of morning (6:00 a.m. to 9:00 a.m.) trips.

Changes in MUNI Bus Ridership by Line. The aggregate impacts on bus ridership discussed in the two preceding sections has presumably resulted in significant changes in ridership on individual MUNI bus lines. Unfortunately, only limited ridership data exist on individual lines for the period before and after BART started service, and these data are limited to bus lines paralleling the BART tracks. The available data show that appreciable changes have occurred only on a few lines paralleling BART. The affected lines are shown in Figure III-2.

As shown in Table III-4, three MUNI express bus lines have experienced appreciable losses of ridership: Line 26X, which parallels BART for its whole length in San Francisco (41% reduction in average ridership per bus); and Lines 14X and 17X which run from Daly City along the Route 101 and Interstate 280 freeways to downtown San Francisco (29% and 17% reductions in average bus ridership, respectively). The other lines registering ridership losses are 14, 14L, 14GL, and 9, all of which also closely parallel BART from Daly City through the Mission District to San Francisco.*

Changes in MUNI Services

A comprehensive study of coordinating the services of MUNI and BART was conducted before the start of BART service on the Daly City Line.** Plan recommendations are keyed to four phases of BART service:

Phase I:	BART begins service in San Francisco.
Phase II:	BART operates at six-minute headways and a 50% fare discount is permitted for travel on MUNI lines to get to and from BART.
Phase III:	BART operates at two-minute headways in the peak period and provides weekend service.
Phase IV:	MUNI Metro (the new streetcar subway line along Market Street which will share stations with BART) opens.

*Ridership data are not available for MUNI's Route 12 which also parallels the Daly City BART Line for most of its length. An "X" in the line designation indicates an express service, and an "L" a limited-stop service.

**MUNI-BART Coordinated Transit Planning Project, Final Report to the BART/MUNI Coordination Board by DeLeuw, Cather & Company, June 1974. (Recommendations were prepared based on analysis of the 1972 MUNI route system.)

BART Line and Station

MUNI Line

FIGURE III-2

PRINCIPAL MUNI BUS LINES AFFECTED BY BART

Table III-4

CHANGES IN RIDERSHIP ON MUNI BUS LINES PARALLELING BART[a]

MUNI Line	Count Location	Average Ridership per Bus		Percent Reduction
		Pre-BART[b]	Post-BART[c]	
9	Mission and South Van Ness Streets	47	35	25%
14	Mission and South Van Ness Streets	45	37	18
14L	Mission and South Van Ness Streets	26	22	16
14GL	Guerrero and 16th Streets	60	40	33
14X	Trumbull and Stoneybrook Streets	64	45	29
17X	Alemany Boulevard and Ocean Avenue	55	46	17
26X	Guerrero and 16th Streets	44	26	41

a. Average of various bus counts taken in the inbound morning peak (approximately 6:45 a.m. to 8:45 a.m.) and outbound afternoon peak (approximately 4:45 p.m. to 6:00 p.m.), except Line 14L, where counts are for 9:00 a.m. to 2:00 p.m. The lines surveyed and number of buses used to compute the averages are: Line 9, 24 and 28 buses pre-BART and post-BART, respectively; Line 14, 20 and 40; Line 14L, 28 and 60; Line 14GL, 32 and 29; Line 14X, 21 and 95; Line 17X, 11 and 32; Line 26X, 26 and 61.

b. Various dates March 1972 to October 1973. BART service between Daly City and San Francisco began November 5, 1973.

c. Various dates November 1973 to October 1974.

Source: San Francisco MUNI (Transit Improvement Project).

To date, Phase I and Phase II BART service conditions have been achieved. Table III-5 details the Phase I and Phase II recommendations of the MUNI/BART coordination study and their current status.*

The table shows that the Phase I recommendations, which mostly extend MUNI lines to BART stations, were all implemented. Phase II recommendations for improved feeder bus coverage were also mostly implemented. However, the more extensive Phase II recommendations for downgrading bus services paralleling BART have generally not been implemented at the level recommended; in all cases, the proposals for service reductions were prevented or delayed by public protest. Although BART service resulted in substantial drops in patronage, neither the 14L nor 26X were eliminated, and service reductions on 14GL, 14X, and 17X have all been less than recommended as a result of public and political protest at the cutbacks. The cutbacks in service that were allowed waited a full three years after BART Daly City Line service began before they were implemented.

AC Transit Bus Ridership in the East Bay

AC Transit offers local and express bus service within the East Bay and transbay bus service between the East Bay and San Francisco. When BART service started in 1972, AC Transit provided bus service in the East Bay to an eleven-city area west of the Berkeley and San Leandro Hills and stretching from Richmond and San Pablo in the north to Hayward in the South. Since then, AC Transit's service area has increased substantially: service began in Fremont and Newark in 1974 and in areas of central Contra Costa County (Concord, Pleasant Hill, and Orinda) in 1975. In 1974, AC Transit also began operating a number of "BART Express" bus lines to more distant areas of Alameda and Contra Costa Counties. These lines, shown in Figure III-3, are operated under contract to the BART District and serve as bus connections with the BART System for people living within Alameda and Contra Costa Counties but beyond the immediate service area of the East Bay BART lines. Historical bus ridership on all AC Transit services from 1972 is shown in Table III-6.

Most of AC Transit's bus lines connect with the BART System at some point--whether as "parallel" or "feeder" services--and significant changes in ridership patterns have taken place since BART's introduction. However, BART's net impacts are difficult to establish from the aggregate ridership data in Table III-6 given the large month-to-month fluctuations caused by seasonal and other influences, and a generally increasing trend in bus ridership. In the seven months, February through August 1972 (before BART service), average East Bay bus ridership was 117,900 trips per

*None of the Phase III or Phase IV recommendations have been implemented.

Table III-5

BART-RELATED CHANGES IN MUNI BUS SERVICES

MUNI Line	Recommendation[a]	BART Station(s) or Route Served	Status 1976[b]	Number of One-Way Vehicle Trips per Weekday 1972	Recommended[a]	1976[b]
PHASE I	RECOMMENDATIONS[c]					
23	Extend Line 23 north to 24th Street BART Station	24th Street Mission	Implemented	41	65	54
25, 80	Combine Line 25 and Line 80	Powell Street	Implemented	115/89	115	124
51	Extend Line 51 west to Glen Park BART Station	Glen Park	Implemented	107	107	115
53	Extend Line 53 west to 16th Street BART Station	16th Street Mission	Implemented	64	65	70
PHASE II	RECOMMENDATIONS[d]					
10	Reroute Line 10 east of Glen Park BART Station to Bayshore Boulevard	Glen Park	Protested and not implemented	106	106	107
14GL	Adjust service on Line 14GL	Mission Corridor	Protested and only partially implemented	9 (5 one-way)	9 (all one-way)	14
14L	Eliminate Line 14L	Mission Corridor	Protested and not implemented	58	--	30
14X	Adjust service on Line 14X	Daly City - San Francisco via Freeway	Partially implemented	44 (16 one-way)	22 (all one-way)	28
15	Eliminate turnback of Line 15 at Arleta and through-route to Phelan Avenue	Balboa Park	Protested and not implemented	126	150	184
17X	Adjust service on Line 17X	Daly City - San Francisco via Freeway	Protested and only partially implemented	39 (6 one-way)	18 (all one-way)	29
26	Shorten Line 26 to Alemany Boulevard at Arch Street	Mission Corridor	Not implemented	100	100	99
26	Reroute Line 26 from Miguel Street to Chenery Street	Mission Corridor	Not implemented	100	100	99
26X	Eliminate Line 26X	Mission Corridor	Protested and not implemented	13 (7 one-way)	--	4
36	Reroute Line 36 to Balboa Park and Daly City BART Stations	Daly City, Balboa Park	Partially implemented No service to Daly City BART	53	73	53
44, 51	Combine Lines 44 and 51	Glen Park	Not implemented	55/107	89	53/115
52	Increase Line 52 headways	Balboa Park	Implemented	62	55	54
72	Extend Line 72 south to Daly City BART Station	Daly City	Substitute service implemented	67	67	67
81	Reroute Line 81 to Balboa Park BART Station and extend to Ocean View District	Balboa Park	Implemented	43	73	42
K	Extend Line K east to Balboa Park Station	Balboa Park	Substitute service implemented	149	149	139

a. Source: MUNI-BART Coordinated Transit Planning Project, Final Report.
b. Source: San Francisco MUNI, Scheduling Department (Effective December 1976).
c. Recommended for implementation immediately after BART began service.
d. Recommended for implementation when BART reached six-minute headways and when the 50% MUNI transfer discount was instituted.

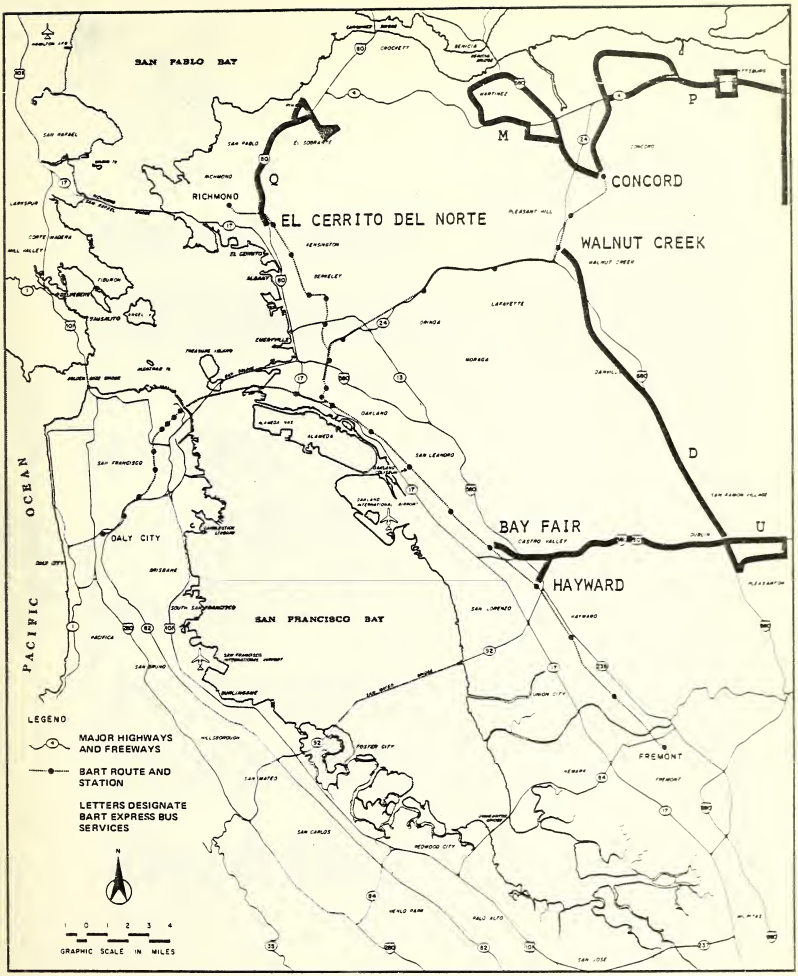

FIGURE III-3
BART EXPRESS BUS SERVICES

Table III-6 (Part 1)

DISTRIBUTION OF AC TRANSIT RIDERSHIP AMONG SERVICES
1972-1974

Year	Month	One-Way Transit Trips per Weekday							Transfers
		East Bay	Transbay[a]	Richmond Dial-a-Ride	Fremont & Newark[b]	BART Express[c]	BART Feeder[d]	Total	BART-to-Bus
1972	January	123,668	51,251	--	--	--	--	174,919	--
	February	125,845	52,271	--	--	--	--	178,116	--
	March	123,237	51,994	--	--	--	--	175,231	--
	April	128,515	53,113	--	--	--	--	181,628	--
	May	127,210	52,681	--	--	--	--	179,891	--
	June	115,524	49,265	--	--	--	--	164,789	--
	July	104,931	45,556	--	--	--	--	150,487	--
	August	100,310	46,532	--	--	--	--	146,842	--
	September	122,147	51,336	--	--	--	--	173,483[e]	--
	October	129,124	53,340	--	--	--	--	182,464	--
	November	126,996	53,781	--	--	--	--	180,777	--
	December	113,510	48,816	--	--	--	--	162,326	--
1973	January	119,889	52,303	--	--	--	--	172,192	--
	February	124,190	55,102	--	--	--	--	179,292[f]	--
	March	125,067	56,810	--	--	--	--	181,877	--
	April	124,484	55,430	--	--	--	--	179,914	6,171
	May	128,553	56,905	--	--	--	--	185,458	6,317
	June	117,908	54,968	--	--	--	--	172,876	6,462
	July	107,933	50,089	--	--	--	--	158,022	6,608
	August	101,767	51,687	--	--	--	--	153,454	6,754
	September	126,445	57,264	--	--	--	--	183,709	6,899
	October	132,180	58,752	--	--	--	--	190,932	7,045
	November	125,723	59,989	--	--	--	--	185,712	7,230
	December	119,080	56,245	--	--	--	--	175,325	7,416
1974	January	127,104	60,892	--	--	--	--	187,996	7,601
	February	138,125	64,177	--	--	--	--	202,302	8,081
	March	145,982	63,867	--	--	--	--	209,849	8,562
	April	125,272	66,400	--	--	--	--	191,672	9,042
	May	134,408	65,006	--	--	--	--	199,414	8,343
	June	130,907	62,882	--	--	--	--	193,789	7,747
	July	--	--	--	--	--	--	--[g]	--
	August	--	--	--	--	--	--	--[g]	--
	September	120,805	50,795	634	--	--	--	172,234[h]	8,412
	October	135,330	42,976	808	--	--	--	179,114	11,391
	November	131,741	44,907	768	--	--	--	177,416	12,068
	December	136,581	43,130	1,007	2,095	2,305	--	185,118	11,836

Table III-6 (Part 2)

DISTRIBUTION OF AC TRANSIT RIDERSHIP AMONG SERVICES
1975-1976

Year	Month	One-Way Transit Trips per Weekday							Transfers
		East Bay	Transbay[a]	Richmond Dial-a-Ride	Fremont & Newark[b]	BART Express[c]	BART Feeder[d]	Total	BART-to-Bus
1975	January	138,794	43,362	891	2,397	2,311	--	187,755	12,844
	February	140,931	44,195	858	2,168	2,149	--	190,301	12,275
	March	142,336	44,958	808	2,211	2,111	--	192,424	12,027
	April	145,674	45,160	957	2,404	2,323	--	196,518	12,496
	May	142,573	43,793	924	2,588	2,434	--	192,312	12,497
	June	114,287	36,364	932	2,710	2,845	--	157,138	11,774
	July	109,743	31,974	865	1,897	2,440	--	146,919	12,400
	August	102,105	33,549	622[i]	1,935	2,970	--	141,181	12,278
	September	136,718	37,404	--	2,756	2,827	989	180,694	12,134
	October	145,804	41,135	--	2,905	2,993	1,193	194,030	13,391
	November	143,694	42,544	--	3,093	3,081	1,464	193,876	14,624
	December	132,726	40,201	--	3,063	3,157	1,817	180,964	13,129
1976	January	143,457	44,710	--	3,303	3,417	1,929	196,816	13,728
	February	144,947	44,375	--	3,333	3,595	2,083	198,333	13,660
	March	145,863	46,504	--	3,281	3,609	2,027	201,284	13,253
	April	140,143	39,620[j]	--	3,425	3,514	2,033	188,735	13,483
	May	146,984	43,543[j]	--	3,577	3,575	2,144	199,823	13,665
	June	126,915	40,107	--	3,344	3,600	2,057	176,023	12,775
	July	119,546	38,001	--	3,366	3,606	1,954	166,473	11,064
	August	117,053	37,237	--	3,151	3,615	2,002	163,058	12,427
	September	141,901	42,385	--	3,551	3,951	2,859	194,650	13,496
	October	152,720	45,947	--	4,031[k]	4,144[l]	3,013	209,855	14,530

a. Transbay ridership includes an undetermined number of riders traveling entirely within the East Bay on transbay lines.
b. Originally, contract services operated by AC Transit outside the AC Transit District; now part of the District.
c. Services operated by AC Transit under contract to BARTD as "BART Express" services.
d. Feeder services to Concord, Pleasant Hill, and Orinda BART stations. Concord service began September 8, 1975. Pleasant Hill service began December 8, 1975; Orinda service began September 20, 1976.
e. BART Fremont Line service began September 11, 1972.
f. BART Richmond Line service began January 29, 1973.
g. AC Transit strike, July 1 to August 31, 1974.
h. BART transbay service began September 16, 1974.
i. Richmond Dial-a-Ride service discontinued August 1975.
j. MUNI strike, April 1 to May 7, 1976.
k. Fremont Dial-a-Ride service began October 18, 1976.
l. Distribution of the 4,144 trips among the five BART express lines was: Pinole to El Cerrito BART station, 238 trips (6%); Dublin, San Ramon, Danville, Alamo to Walnut Creek BART station, 796 trips (19%); Martinez, Brentwood, Oakley, Antioch, Pittsburgh, West Pittsburgh to Concord BART station, 1,828 trips (44%); Livermore, Pleasanton, Dublin, San Ramon to Hayward and Bay Fair BART stations, 1,282 trips (31%).

Source: AC Transit District. Reports of daily unaudited revenue, mileage, and passengers excluding mail carrier and charter revenues, also refunds, etc. (Form 34). Average for all weekdays excluding public holidays.

weekday. In the seven months, February through August 1973 (after BART service was operating on the Fremont and Richmond BART Lines), average ridership on AC Transit's East Bay lines was 116,200 trips per weekday. The drop of 1,700 trips per weekday represents less than 2% of the total--suggesting that diversion from bus to BART has been offset by new trips using AC Transit as a feeder service to BART.

Since then, East Bay bus ridership has risen considerably. In the same seven months, February through August 1976, ridership averaged 134,500 trips per weekday, 15% higher than in 1972. Significant ridership increases have also been recorded on AC Transit's other new services. In October 1976, ridership on the Fremont and Newark services averaged 4,000 trips per weekday; on the Concord, Pleasant Hill, and Orinda services, 3,000; and on the BART express services, 4,100. Since most of these bus lines are oriented toward serving BART stations, many of the trips represent access trips to and from BART. The heavy use of AC Transit buses by people to get to and from BART stations is also illustrated in Table III-6 by the number of transfers recorded from BART to bus. In October 1976, these transfers averaged 14,500 per weekday.

The following sections analyze the two components of BART's impacts--diversion of "line-haul" trips from bus to BART and use of bus for "access" trips to and from BART--to estimate BART's impacts on overall ridership.

Diversion of Trips from East Bay AC Transit to BART. As detailed in Table II-5, the most recent (May 1976) survey of BART's ridership shows that 18% of BART trips made within the East Bay were previously made by bus. Nearly all these trips were on AC Transit. A further 48% of trips were made by automobile or some other mode, and the remaining 32% of trips were not made before BART. Of these 32%, about 8% are estimated as new trips, i.e., trips which would probably not be made without BART.* It can be assumed that without BART, the remaining 24% would be split between bus and auto (or other mode) in the same proportions (0.26 to 0.74) as the split of trips that actually were made before BART. This assumption gives the result that, if BART were not available, 23% of the 41,600 daily trips currently made on BART within the East Bay,** or 9,700 trips in total would be made on AC Transit buses. These 9,700 trips represent about 6% of current ridership on AC Transit's East Bay services (152,700 trips per weekday in total).

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*The May 1976 BART Passenger Profile Survey shows that for all BART trips made within the East Bay 31.8% were not made before BART began service: 23.6% because the respondent "didn't live here" or "didn't work here" and 8.2% for other reasons, including "did not have convenient transportation available."

**Average daily East Bay BART ridership, October 1976.

Use of AC Transit Buses To Get to and from BART. The estimated loss of 9,700 daily "line-haul" trips to BART has been more than offset by travelers' use of AC Transit buses to get to or from BART stations. Table III-7 gives estimates of these access trips.

The table shows the distribution of current access modes to and from BART cross-tabulated by the pre-BART travel mode. Two groups of trips are shown: (1) trips made entirely within the East Bay (which have an access trip portion at both origin and destination) and (2) transbay trips (which have an access portion in the East Bay at only one end of the trip). The numbers shown in the table are "access trips"--every single BART journey containing two access trips, one from the origin to BART and the second from BART to the destination.

Numbers in the table marked with a solid circle are estimates of gains in daily access trips for the AC Transit system. These trips (totaling 21,900) represent estimates of entirely "new" bus trips. The numbers marked with a hollow circle, totaling 7,300 trips, represent access bus trips which substitute for previous "line-haul" bus trips. The number marked with a square, 2,700 trips, represents a loss of bus access trips on the AC Transit system. (These are trips which previously transferred between East Bay local lines and transbay lines.)*

Net BART Impacts on AC Transit East Bay Ridership. The analysis summarized in Table III-7 indicates that BART has had the net effect of adding 26,500 access trips daily to AC Transit's East Bay ridership (including those access trips which substitute for previous line-haul trips). The estimate of 26,500 access trips gained by the bus system clearly more than offsets the 9,700-trip estimate of losses in line-haul trips diverted from AC Transit to BART.**

Changes in Ridership on East Bay AC Transit Lines. Growth in AC Transit ridership over the period before and after BART occurred on many lines of the network--some of them remote from BART, some paralleling BART lines, and some acting as connecting services to BART. Only on a few lines can changes in bus ridership be attributed to the start of BART service. Table III-8 summarizes pre- and post-BART ridership on the principal AC Transit bus lines paralleling the BART Fremont and Richmond Lines.

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*Note, however, that since a free transfer is offered between transbay and local lines of AC Transit (except where the trip extends into a different fare zone), the associated loss of fare revenue is much less than suggested by the 2,700-trip estimate.

**Of course, the access trips are generally shorter and generate a much lower average revenue per trip because of the 50% BART-AC Transit tranfer discount.

Table III-7

USE OF EAST BAY AC TRANSIT TO GET TO AND FROM BART

	Number of Trips to and from BART Using		Total Access Trips[a]
	AC Transit Bus	Walking, Automobile, or Other Mode	
Trips Within the East Bay			
New trips	1,700 ●	5,200	6,900[b]
Previously used AC Transit bus	6,600 ○	12,800	19,400[c],
Previously walked, used automobile or other mode	12,000 ●	44,900	56,900[c]
Subtotal, trips within East Bay	20,300[e]	62,900	83,200
Transbay Trips			
New trips	700 ●	3,500	4,200[f]
Previously used transbay bus and transferred to or from another AC Transit bus	700 ○	2,700 ■	3,400[g],
Previously used transbay bus and walked or used some other access mode in the East Bay	4,800 ●	19,600	24,400[g],
Previously used automobile or some other mode	2,700 ●	18,400	21,100[h]
Subtotal, transbay trips	8,900	44,200	53,100
Total trips to and from BART	29,200	107,100	136,300

● : Access trips representing a gain to AC Transit.
○ : Access trips substituting for pre-BART AC Transit.
■ : Access trips representing a loss to AC Transit.

See footnotes on following pages.

Table III-7 (cont.)
USE OF EAST BAY AC TRANSIT TO GET TO AND FROM BART

a. All numbers are daily access trips to and from BART, with a (single) origin-to-destination trip on BART counting as two access trips--one from the origin to BART and one from BART to the destination. Thus, the total shown for access trips within the East Bay (83,200) is two times average daily East Bay BART ridership. However, an East Bay access trip is made at only one end of a transbay BART trip. Therefore, the total shown for the East Bay access portion of transbay trips (53,100) is equal to only one times average daily transbay BART ridership. Both the 83,200- and 53,100-trip control totals are average daily trips for October 1976.
b. The number of new trips (i.e., trips which would probably not be made without BART) is estimated as 8.2% of total BART trips. The May 1976 BART Passenger Profile Survey (1976 PPS) shows that 31.8% of East Bay trip respondents did not make their trip before BART started service. However, 23.6% of these are accounted for by changes in residence or workplace. The remaining 8.2% began making the trip for other reasons, including the availability of convenient transportation. The total estimated number of new trips (6,900) is distributed between the two access modes in the same proportions as the total of trips which were made previously.
c. The distribution of trips among previous modes and current access modes is estimated using the 1976 PPS. Trips shown are estimates of all trips made during the day. These estimates were made from the results of the survey (which was conducted only from 6:00 a.m. to 3:00 p.m. and 7:00 p.m. to midnight) by assuming that the characteristics of trips made in the afternoon peak (3:00 p.m. to 7:00 p.m.) are the same as those of trips made in the morning peak except that afternoon access and egress trips are the "mirror image" of morning egress and access trips, respectively.
d. Previous trips in which a transfer was made between buses are counted as single trips.
e. A relatively small number of trips made to and from BART on other bus systems (such as the Union City and Walnut Creek systems, Greyhound, and Humphrey Go-BART) are included.
f. The number of new trips is estimated as 8.0% of the total. The 1976 PPS shows that 8.0% of BART transbay trips were made for the first time after BART began for reasons other than a change of residence or workplace. The total estimated number of new transbay trips (4,200) is distributed between the two access modes in the same proportions as the total of trips which were made previously.
g. According to the BART Impact Program October 1974 Survey of Transbay Bus Travel, 12.3% of all transbay bus riders transfer to or from another bus in the East Bay and 87.7% walk or use some other access mode. The same distribution is assumed within the total of 27,800 transbay BART trips which previously used transbay bus.

Table III-7 (cont.)
USE OF EAST BAY AC TRANSIT TO GET TO AND FROM BART

h. The total of trips previously made by transbay bus (27,800) are estimated using the analysis of changes in transbay bus ridership presented later in this chapter. The implied percentage of transbay trips previously made by bus is 52%. The (residual) number of trips, estimated as previously made by automobile or other modes (21,100), represents 40% of the total. These percentages agree closely with the results of the BART Impact Program October 1974 Survey of Transbay BART Travel. (See Table II-5.)

The distribution of the totals between AC Transit and other access modes is estimated from the 1976 PPS. In estimating the access mode distribution for BART trips during the entire day, the access mode distribution of afternoon (3:00 p.m. to 7:00 p.m.) trips is assumed to be the "mirror image" of morning (6:00 a.m. to 9:00 a.m.) trips.

Table III-8

AVERAGE WEEKDAY RIDERSHIP ON AC TRANSIT EAST BAY LINES

	Pre-BART	Post-BART		
	April 1972	April 1973	April 1974	April 1975
Hayward-San Leandro-Oakland				
Lines 80, 81, 82, 83	17,200	15,100	17,700	18,400
Lines 30, 32	3,900	500	600	400
Richmond-Oakland				
Lines 31, 33	3,900	2,200	2,600	2,300
Line 72	8,200	7,900	8,100	8,100
Berkeley-Oakland				
Lines 40, 43	16,200	15,000	17,200	18,700

BART Fremont Line service began September 11, 1972.
BART Richmond Line service began January 29, 1973.

Source: AC Transit District, reports of daily passengers (Form 34). Numbers are averages for all weekdays in the month, excluding public holidays.

In the Fremont corridor, combined ridership on Lines 80, 81, 82, and 83 connecting Hayward and Oakland, was 17,200 trips per weekday in April 1972. In April 1973, after the start of Fremont Line service, ridership had fallen to 15,100 trips per weekday on average. However, in April 1974, ridership on the four routes had risen to 17,700 trips, and in April 1975, it was 18,400 trips per weekday. Over the period since BART's opening, diversion of ridership to BART from parallel bus services appears to have been more than offset by increases in bus ridership due to other causes, presumably including the use of bus to get to and from BART. Ridership on Lines 30 and 32, which totaled 3,900 trips per weekday in April 1972, fell drastically following the start of BART service to an average of 500 trips per weekday in April 1973 and has remained at this level since then. (Service on Line 30 was discontinued following the start of BART service.)

Table III-8 shows that ridership on AC Transit Lines 31 and 33, which parallel the Richmond BART Line from Richmond to Oakland, was reduced from a pre-BART level of 3,900 trips per weekday in April 1972 to an average 2,200 trips per weekday in April 1973 (after the start of Richmond Line service). Combined ridership on AC Transit Routes 40 and 43, which also parallel the Richmond Line between Berkeley and Oakland, averaged 16,200 trips per weekday in April 1972. In April 1973, ridership had decreased to 15,000 trips per day, but by April 1975, ridership had again risen to 18,700 trips per day.* Ridership on Line 72 between Richmond and Oakland experienced only a small reduction over the year when BART began service (from 8,200 trips per weekday in April 1972 to 7,900 trips in April 1973). These figures confirm that some riders diverted from bus to BART when the Richmond Line opened. However, they also suggest that the reduction in parallel bus ridership caused by BART was small relative to the subsequent increases in ridership caused by other influences.

Changes in AC Transit East Bay Services

A specific plan for coordinating AC Transit and BART services was not drawn up before East Bay BART service began (as was the case with MUNI in San Francisco). However, considerable effort has been expended in coordinating AC Transit bus services and BART, including establishing an AC Transit/BART Coordination Project. This joint effort by the Metropolitan Transportation Commission, the AC Transit District, and the BART District developed analysis procedures and a series of general recommendations for implementing and improving coordinated transit services.**

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*The small drop from 1972 to 1973 and subsequent increase in ridership may largely be explained by the use of these two bus lines by people getting to and from the North Berkeley and Berkeley BART Stations. It should also be noted that over half the patronage on Lines 40 and 43 is generated in the Foothill-MacArthur Boulevard corridor where BART is not directly competitive.

**AC Transit/BART Service Coordination. Final Report to AC/BART Coordination Project Board of Control, by Alan M. Voorhees & Associates, Inc., September 1974.

BART-related service changes to the AC Transit bus system are listed (chronologically) in Table III-9. The table shows the large number of service changes made on lines to provide or improve feeder service to BART. Since only changes in bus service are shown, the 12th Street Oakland and 19th Street Oakland BART stations are not listed, because the lines serving them remain unchanged. Both these stations are served by many AC Transit bus lines.

The table also illustrates that very few significant reductions in East Bay bus service have resulted from BART's introduction. Of all AC Transit's lines, only Line 30 from Hayward to Oakland has been eliminated completely, and service has been significantly reduced only on the following: Line 32 from Hayward and San Leandro to Oakland (where complete elimination of the line was prevented by public protest) and Lines 31 and 33 between Richmond and Oakland. No significant service cutbacks occurred on Lines 41, 43, or 72 (between Richmond and Oakland) or Lines 80, 81, or 82 (between Hayward and Oakland).

Transbay Bus Ridership

BART's greatest impacts on bus ridership have been in the transbay travel corridor between San Francisco and Oakland. About 26,500 transbay BART trips are made per day in each direction and over a half of these trips were diverted from AC Transit and Greyhound buses.

AC Transit Transbay Bus Ridership. As detailed in Table III-6, in the first three months of 1974, average weekday ridership on AC Transit's transbay lines (including trips made on these lines entirely within the East Bay) was 63,000 trips per day. In the first three months of 1975, following the start of transbay BART service, ridership on transbay bus lines fell to 44,200 trips per day; a drop of 18,800 trips or 30%. In the first three months of 1976, ridership had risen slightly to an average of 45,200 trips per weekday.

Greyhound Transbay Bus Ridership. Table III-1 shows the even sharper drop in ridership in Greyhound's transbay commuter services from the Concord-Walnut Creek area of Contra Costa County before and after the start of transbay BART. In the first three months of 1974, average weekday ridership on Greyhound buses was 12,000 trips per day; in the same period of 1975, ridership averaged 3,400 trips per day, a loss of 8,600 trips or 72%. By the first three months of 1976, average weekday Greyhound ridership had dropped to 1,800 trips per day.

Total Transbay Bus Ridership. Adding together the losses of ridership on both AC Transit and Greyhound transbay lines gives a total ridership drop of 27,400 trips per weekday or 13,700 trips per day in each direction.

Table III-9

CHRONOLOGICAL LISTING OF BART-RELATED CHANGES
IN AC TRANSIT BUS SERVICES

Line(s)	BART Station(s) or Route Served	Change
September 1972--BART Fremont Line Service		
30	Hayward - Oakland	Service discontinued
32	Hayward - Oakland	Service reduced (public protest prevented discontinuation)
14, 32, 36	Lake Merritt	Rerouted to BART
N	San Leandro	Rerouted to BART
53	Fruitvale	Service increased and rerouted to BART
54, 64, 79	Fruitvale	Rerouted to BART
55	San Leandro	Rerouted to BART
56, 57	Coliseum	Rerouted to BART
90, 91, 91A, 92	Hayward	Rerouted to BART
91, 82	South Hayward	Rerouted to BART
60, 66	San Leandro, Bay Fair,	New lines to BART (later extended)
62A	Bay Fair	New line to BART (later combined with 93A)
66	Coliseum	New line to BART (peak period), later extended
81, 82 (Night)	San Leandro	Rerouted to BART
84	Bay Fair	New line routed to BART
80, 81, 81A, 82, 86	Hayward	Rerouted to BART
81B	San Leandro	New line to BART (later rerouted)
93, 93A	Bay Fair	Rerouted to BART
January 1973--BART Richmond Line Service		
31, 33	Richmond - Oakland	Service reduced
H	North Berkeley	Provided local service to BART
7	Berkeley	Rerouted to BART
14	MacArthur	Rerouted to BART
15	Berkeley, Ashby, MacArthur	Rerouted to BART
17	Ashby, MacArthur	Rerouted to BART
43, 43A	North Berkeley, Berkeley	Rerouted to BART
51A	El Cerrito Plaza, North Berkeley	Rerouted to BART
65	North Berkeley, Berkeley, Ashby	Rerouted to BART
67	El Cerrito Plaza, Berkeley	Rerouted to BART
69	Richmond	Rerouted to BART
72	Richmond, El Cerrito Plaza	Rerouted to BART
72C	El Cerrito del Norte	Rerouted to BART
40	Berkeley	Line extended to BART
78	Richmond, El Cerrito del Norte, El Cerrito Plaza	Line extended to BART
88	North Berkeley	Line extended to BART
70	El Cerrito del Norte, El Cerrito Plaza	New line to BART
72B	El Cerrito del Norte, El Cerrito Plaza	New line to BART (later discontinued)
72M	El Cerrito del Norte	Additional off-peak service provided

Table III-9 (cont.)
CHRONOLOGICAL LISTING OF BART-RELATED CHANGES
IN AC TRANSIT BUS SERVICES

Line(s)	BART Station(s) or Route Served	Change
May 1973--BART Concord Line Service		
17	Rockridge	Rerouted to BART
C	MacArthur	BART to San Francisco shuttle service
September 1974--BART Transbay Service		
E	Rockridge, MacArthur	Rerouted to BART
C	MacArthur	BART-San Francisco shuttle service discontinued
L-1	El Cerrito del Norte	Rerouted to BART
K, R, S	Hayward - San Francisco	Service reduced
A, C	Oakland - San Francisco	Service reduced
E, F	Berkeley - San Francisco	Service reduced
O	Lake Merritt	Service to BART discontinued
12, 88	Oakland West	Rerouted to BART
80, 83	Oakland West	Rerouted to BART (westbound direction)

Source: AC Transit District (Schedules Department).

All the AC Transit ridership figures quoted here are for total ridership on AC Transit transbay bus lines, but some trips on transbay lines never cross the Bay. A more accurate picture of BART's impacts on transbay bus ridership is given by the data summarized in Figure V-2 in Chapter V. This figure shows estimated actual midweek daytime (6:00 a.m. to 8:00 p.m.) transbay bus ridership on AC Transit and Greyhound.

Based on the data displayed in Figure V-2, a regression analysis of the trend in total transbay bus ridership before transbay BART service started in September 1974 shows that ridership was increasing at an average rate of 1,460 one-way daily trips each year. The regression line reaches a level of 31,100 trips per day in October 1974. A corresponding regression analysis of the trend in transbay bus ridership since transbay service started shows that from November 1974 through October 1976, ridership has been increasing at a rather higher rate (2,410 one-way daily trips per year). Extrapolation of this trend line back to October 1974 gives an intercept of 17,200 trips. The difference between the "before" and "after" trend line intercepts is 13,900--almost exactly the same result as given by the above analysis (suggesting that the loss in ridership on AC Transit's transbay lines was mainly people traveling across the Bay, and not those traveling on these lines within the East Bay).

Changes in Ridership on AC Transit Transbay Lines. Changes in ridership on each of AC Transit's transbay lines are shown in Table III-10. Comparing the average weekday ridership shown in the table for September 1974 (immediately before transbay BART) with the ridership for October 1974 (immediately after) shows a drop of 7,900 trips per day. This drop is nearly all accounted for by decreased ridership on just five lines: the A, C, E, F, and R Lines. As shown on Figure III-4, these lines all parallel BART for much their length. The L Line, which also approximately parallels BART (along the Richmond Line), shows no appreciable change in ridership between September and October 1974.* (Diversion of ridership from transbay buses to BART has probably been lower on the Richmond Line than on the Concord or Fremont Lines largely as a result of the need to transfer between BART trains on Richmond-San Francisco trips. But in the case of travel by AC Transit's L Line from Richmond to San Francisco via I-80, the bus would show a travel time advantage even over direct BART service to downtown San Francisco.)

Table III-10 shows that between October 1974 and October 1975, most lines experienced further losses in ridership (especially the A, F, and R Lines), but these losses were more than regained between October 1975 and October 1976.

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*Comparing the data given in Table III-10 for October 1973 (a year before transbay BART) with that for October 1974 shows a much larger total reduction in transbay ridership (16,500 trips), but the distribution among lines is similar. The relatively low ridership levels in September 1974 probably reflect residual effects of the AC Transit strike in the two preceding months.

Table III-10

AVERAGE WEEKDAY RIDERSHIP ON AC TRANSIT TRANSBAY LINES

Line	Pre-Transbay BART		Post-Transbay BART		
	October 1973[a]	September 1974[b]	October 1974[c]	October 1975[d]	October 1976[e]
A	4,135	3,742	2,365	1,937	2,318
B	2,393	2,168	1,767	1,743	1,840
C	4,496	5,089	2,982	2,952	3,072
E	3,665	3,650	2,243	2,323	2,436
F	10,725	9,344	8,076	7,862	8,788
G	1,400	1,109	1,131	1,213	1,302
H	1,531	1,174	1,285	1,241	1,395
K/R	11,818	9,930	8,157	7,161	9,053[f]
L	6,336	5,264	5,454	5,427	5,599
N	6,294	5,100	5,070	5,155	5,634
O/W	5,173	4,544	4,477	4,576	4,917
Y	97	152	199	178	202
T	1,375	1,053	1,229	1,193	1,028
Total	59,438	52,319	44,435	42,961	47,584

a. October 1 - October 26, 1973.
b. September 3 - September 13, 1974 (two weeks between end of AC Transit strike on August 31 and start of transbay service on September 16).
c. September 30 - October 25, 1974.
d. October 6 - October 31, 1975.
e. October 4 - October 29, 1976.
f. Includes S Line.

Source: AC Transit District (Form 34 reports). Average for all weekdays excluding public holidays. Ridership includes trips made on transbay lines entirely within the East Bay.

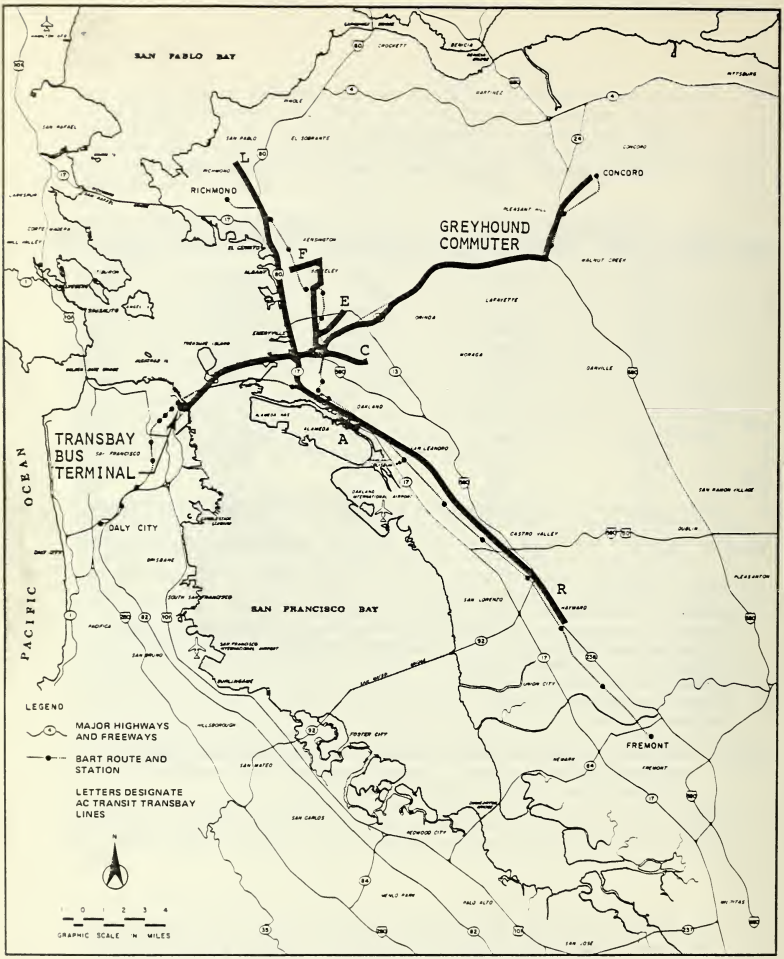

FIGURE III-4

PRINCIPAL AC TRANSIT AND GREYHOUND

TRANSBAY BUS LINES AFFECTED BY BART

Changes in Transbay Bus Services

AC Transit Transbay Bus Service Levels.* In response to reduced transbay bus ridership, service levels on AC Transit's transbay lines have been cut back, but no lines have been eliminated completely. The cutbacks are indicated by the summary of scheduled bus-miles given in Table III-11. From a base level of 35,800 weekday bus-miles scheduled on transbay lines in December 1973, bus-miles decreased 3% to 34,900 by December 1974 (soon after the start of transbay BART service and before adjustments had been fully made in reaction to the drop in ridership) and 15% to 30,400 by December 1975. The same number of bus-miles (30,400) was scheduled effective December 1976.

Correspondingly, the number of buses in transbay service during the morning peak period was 319 buses in December 1973, 286 buses in December 1974, 252 buses in December 1975, and 251 buses in December 1976. The reduction of 67 buses from 1973 to 1975 is a 21% decrease.

The K/R/S Line paralleling the BART Fremont Line has experienced the greatest reduction in service--from 9,638 scheduled bus-miles per day in December 1973 to 7,443 bus-miles per day in December 1975, a reduction of 23%. In 1973, 82 buses were scheduled on this line during the morning peak period at approximately 5-minute headways. In 1975, 57 buses were scheduled at approximately 10-minute headways.

Service on the A Line has also been cut back significantly--from 1,855 scheduled bus-miles per day (nine buses at 10-minute headways during the morning peak) in December 1973 to 1,141 bus-miles per day (four buses at 20-minute headways during the morning peak) in December 1975, a bus-mile reduction of 38%. However, as measured by scheduled bus-miles, service on the C, E, and F Lines has been cut back relatively little over the same period--4%, 10%, and 1%, respectively--in spite of fairly large losses in ridership.** On the C Line, morning peak period average headways have increased from about 7 minutes to 8 minutes and on the E Line from 10 minutes to 12 minutes; on the F Line, they are unchanged at 5 minutes. In December 1973, a combined total of 137 buses were scheduled for service on the A, C, E, F, and K/R/S Lines during the morning peak period. By December 1975, this number had fallen to 94 buses, a drop of 31%.

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*Data given in this section are summarized from AC Transit District Scheduling Department, Forms 38.

**The increase in bus-miles for the F Line from 4,090 in December 1973 to 4,589 in December 1974 reflects a pre-transbay BART increase in service (effective March 1974). If the 4,589 figure is taken as the pre-BART estimate, the decrease to the post-BART level in December 1975 is 12%.

Table III-11

WEEKDAY BUS-MILES SCHEDULED ON AC TRANSIT TRANSBAY LINES

AC Transit Transbay Line	Pre-Transbay BART	Post-Transbay BART		
	December 1973[a]	December 1974[b]	December 1975[c]	December 1976[d]
A	1,855	1,235	1,141	1,141
B	1,471	1,431	1,311	1,214
C	2,102[e]	2,008	2,010	2,058
E	1,537	1,544	1,385	1,464
F	4,090	4,589	4,055	4,126
G	858	819	705	715
H	987	921	843	848
K/R/S	9,638	8,748	7,443	7,634
L	4,656	4,803	4,729	4,742
N/V	4,319	4,151	4,129	4,224
O/W	2,928	3,184	3,320	3,273
T	1,234	1,236	1,236	895
Y	86	188	188	188
AC Transit Transbay Total	35,761	34,857	32,495	32,522
AC Transit East Bay Total	53,589	63,410	67,625	71,168
AC Transit Total All Lines	89,350	98,267	100,120	103,690

a. Effective December 3, 1973.
b. Effective December 2, 1974.
c. Effective December 8, 1975.
d. Effective December 6, 1976.
e. Excludes C Line shuttle service between Rockridge Station and Transbay Bus Terminal.

Source: AC Transit District Scheduling Department (Form 38 Reports).

Greyhound Transbay Bus Service Levels.* Corresponding to the diversion of large numbers of trips to BART's Concord Line service, Greyhound transbay commuter bus services have also been reduced drastically. In March 1974, when Greyhound carried 12,200 trips per day on its transbay lines, 242 vehicle-trips per day were made. By the end of 1976, with ridership of about 1,700 trips per day, only 42 daily trips were made. This represents more than an 80% reduction in service--approximately in proportion to the drop in ridership. The load factor (number of seats occupied) has fallen from about 50 in 1974 to about 40 currently. Greyhound has also discontinued all its off-peak weekday service in the Concord corridor since transbay BART service began.

*Data given in this section were provided by Greyhound Lines.

IV. CHANGES IN HIGHWAY TRAFFIC VOLUMES

San Francisco Bay Bridge Traffic

In an attempt to isolate BART's impacts on highway traffic from the influences of other factors, most of this chapter analyzes traffic volumes on the four major bridges across San Francisco Bay. The four bridges, whose locations are shown in Figure I-2, are the San Francisco-Oakland Bay Bridge, the San Mateo-Hayward Bridge, the Richmond-San Rafael Bridge, and the Golden Gate Bridge. The most important of the bridges is the San Francisco-Oakland Bay Bridge (generally referred to as the Bay Bridge). Typically, well over 90,000 vehicles per day travel on the five lanes in each direction. BART service through the Transbay Tube parallel to the Bay Bridge was expected to have major impacts on this traffic volume.

The Golden Gate Bridge connects San Francisco to the residential areas of Marin County, and like the Bay Bridge, it carries high volumes of commuter traffic to and from the City. Often, over 50,000 vehicles per day cross the bridge in each direction. Since there is no reason to suppose that BART has affected traffic volumes on the Golden Gate Bridge, it forms a logical control site with which to compare changes in Bay Bridge traffic volumes, although other changes have occurred in the Golden Gate corridor--including improved bus service and car pool incentives--which affect its use as a control.

The San Mateo-Hayward Bridge and the Richmond-San Rafael Bridge carry about 15,000 and 10,000 vehicles per day in each direction, respectively--much lower traffic volumes than the San Francisco-Oakland and Golden Gate Bridges. Nevertheless, comparing them with the Bay Bridge is useful since (1) the BART Fremont Line is a possible alternative to the San Mateo-Hayward Bridge for some travel from southern Alameda County to San Francisco; and (2) traffic on the Richmond-San Rafael Bridge is essentially unaffected by BART, making it another "control site."

Traffic volumes on the four bridges are particularly amenable to analysis, since they are toll bridges and keep continuous and consistent records of traffic volumes on a day-to-day basis. Therefore, a much more precise time-series analysis of traffic volumes is possible than for other highway facilities where only infrequent counts are taken.

Trend and Seasonal Components of Bridge Traffic. Figures IV-1, IV-2, IV-3, and IV-4 show average midweek traffic volumes on, respectively, the San Francisco-Oakland Bay Bridge, the Golden Gate Bridge, the San Mateo-Hayward Bridge, and the Richmond-San Rafael Bridge.* Until the fall of

*The data shown are averages of midweek (Tuesday, Wednesday, and Thursday) 24-hour traffic volumes. These data were selected for analysis because traffic volumes on these days generally show very much smaller day-to-day fluctuations than do data for Mondays and Fridays. Data for public holidays (falling on a Tuesday, Wednesday, or Thursday) and for Tuesdays or Thursdays adjacent to long holiday weekends were also excluded to minimize extraneous influences.

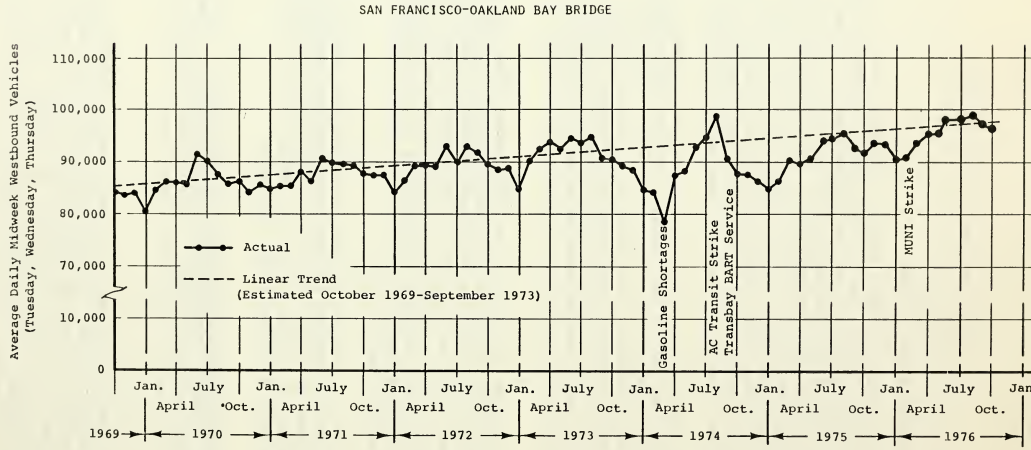

FIGURE IV-1

AVERAGE DAILY MIDWEEK TRAFFIC ON THE SAN FRANCISCO-OAKLAND BAY BRIDGE, OCTOBER 1969 - OCTOBER 1976

Source: CALTRANS Toll Bridge Administration, Daily Totalizer Volume Counts.

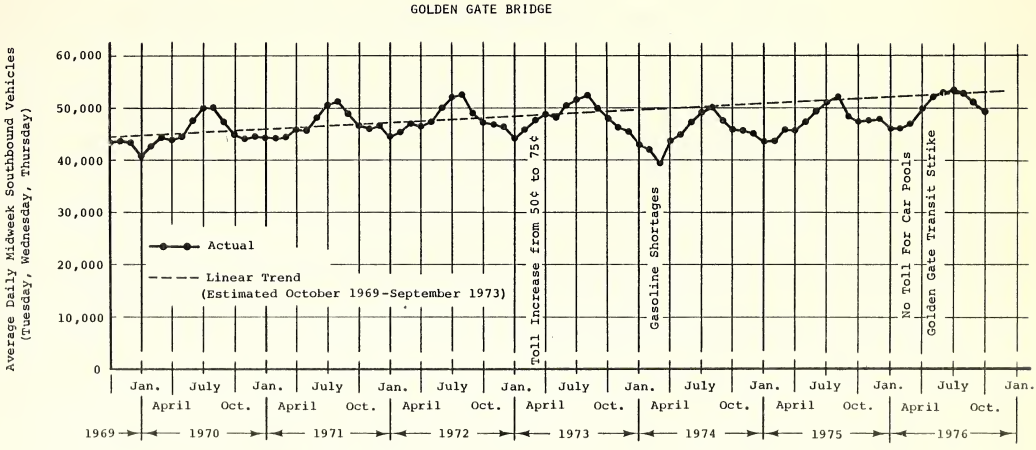

FIGURE IV-2

AVERAGE DAILY MIDWEEK TRAFFIC ON THE GOLDEN GATE BRIDGE, OCTOBER 1969 - OCTOBER 1976

Source: Golden Gate Bridge Highway and Transportation District, Summary Vehicle Counts.

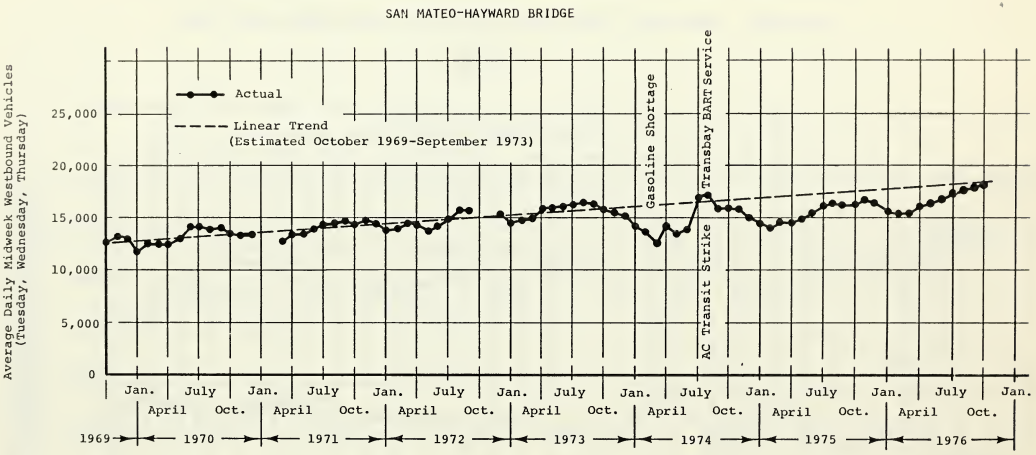

FIGURE IV-3

AVERAGE DAILY MIDWEEK TRAFFIC ON SAN MATEO-HAYWARD BRIDGE, OCTOBER 1969 - OCTOBER 1976

Sources: CALTRANS Toll Bridge Administration, Daily Totalizer Volume Counts.

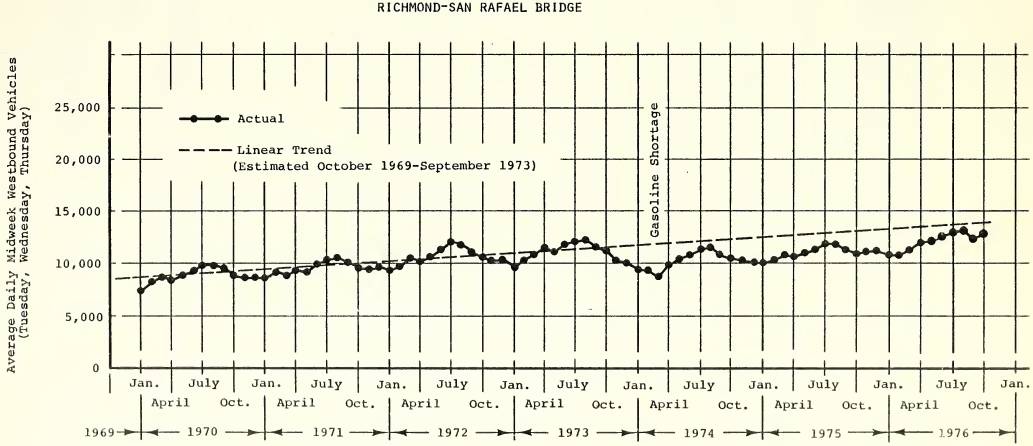

FIGURE IV-4

AVERAGE DAILY MIDWEEK TRAFFIC ON RICHMOND-SAN RAFAEL BRIDGE, OCTOBER 1969 - OCTOBER 1976

Sources: CALTRANS Toll Bridge Administration, Daily Totalizer Volume Counts.

1973, when the "gasoline crisis" first caused reduced travel volumes, two components of volume variation are apparent on all four bridges: (1) a recurring pattern of seasonal variation over the months of the year superimposed on (2) a steady underlying growth in traffic volumes. Thus, the traffic volume for a given month can be considered the sum of two parts:

- A positive "trend" component which increases uniformly over time, and
- A "seasonal" component which depends on the month of the year (and is, for example, positive in July and negative in January).

Mathematically, these two components of traffic volume can be expressed by the following linear "trend-plus-seasonal" model:

$$y_t = A + Bt + \sum_{m=1}^{12} C_m M_m$$

where

y_t is the average daily traffic volume for month t.

t is time measured in elapsed months (starting at t = 1 in October 1969 and running to t = 48, say, in September 1973).

M_m (m = 1 to 12) is a function associated with each of the 12 months of the year (m = 1 for January, m = 2 for February, etc.) such that M_m takes on a value of 1 if t is the m^{th} month of the year (i.e., if [t + 21] = m[modulo 12]), and is zero otherwise.

A is a constant representing the "base level" traffic volume at t = 0 (in September 1969).

B is a constant describing the slope of the underlying linear trend line.

C_m (m = 1 to 12) are constants (seasonal indices) representing the additive seasonal component of traffic associated with the m^{th} month of the year. The summation of C_m over m = 1 to 12 is zero.

Using linear regression analysis, the trend-plus-seasonal model was estimated for each of the four bridges, using traffic volume data for the 48 months from October 1969 through September 1973 in each case. The results

of the regressions are given in Tables IV-1 and IV-2.* Table IV-1 shows estimates of the trend line intercept and slope. Table IV-2 shows the indices of monthly variation above and below the trend. The seasonal indices are also shown graphically in Figure IV-5.

Long-Term Trends. As is illustrated by Figures IV-1 and IV-2 and summarized in Table IV-1, traffic on the San Francisco-Oakland Bay Bridge and the Golden Gate Bridge increased steadily from the fall of 1969 to the fall of 1973, when the "gasoline crisis" first became apparent. For the Bay Bridge, the linear trend line for the four years shows a rate of increase of nearly 1,800 vehicles per midweek day each year. This is an annual increase of 2.0% of the mean traffic volume for the whole period (88,300 vehicles per day). On the Golden Gate Bridge, the corresponding annual rate of increase over the four years to September 1973 was 1,100 vehicles per day, an annual incrase of 2.4% of the mean midweek traffic volume over the period (46,800 vehicles per day).

As shown in Figures IV-3 and IV-4 and Table IV-1, traffic on the San Mateo-Hayward and Richmond-San Rafael Bridges also increased steadily over the same four-year period, but at much higher percentage rates. On the San Mateo-Hayward Bridge, the annual increase in midweek traffic was about 900 vehicles per day (6.0% of the four-year mean). On the Richmond-San Rafael Bridge, the rate of increase was about 800 vehicles per day (8.4% of the four-year mean).

Seasonal Variations. Table IV-2 and Figure IV-5 summarize the marked variations in bridge traffic volumes above and below the trend that occur as a function of the month of the year. The Golden Gate Bridge shows a particularly consistent recurrent seasonal pattern, with traffic volumes typically varying between a maximum in August (about 4,300 vehicles per day above the trend line) and a minimum in January (about 3,900 vehicles per day below the trend). The other three bridges all show similar patterns of variation. Traffic levels are high in the summer, low in winter, and close to the mean in the spring and fall months of April, May, September, and October.

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*The "goodness of fit" of the model for the average midweek daily traffic on the four bridges is indicated by the following coefficients of multiple determination (R^2): San Francisco-Oakland Bay Bridge, $R^2 = 0.91$; Golden Gate Bridge, $R^2 = 0.97$; San Mateo-Hayward Bridge, $R^2 = 0.93$; Richmond-San Rafael Bridge, $R^2 = 0.97$.

Table IV-1

TREND COMPONENT OF VARIATION IN BRIDGE VEHICLE TRAFFIC
(Results of Trend-Plus-Seasonal Regressions for Period October 1969 to September 1973)

	Average Midweek Daily Traffic (AMDT): Vehicles in One Direction				
	Trend Intercept (base level AMDT, October 1969)	Trend Average (mean AMDT, October 1969 to September 1973)	Trend Slope (AMDT increase per month)	Annual Trend (AMDT increase per year)	Percent Annual Trend Increase[a]
San Francisco-Oakland Bay Bridge	84,626	88,270	149	1,785	2.0%
Golden Gate Bridge	44,521	46,780	92	1,110	2.4
San Mateo-Hayward Bridge	12,368	14,111	71	851	6.0
Richmond-San Rafael Bridge	8,161	10,014	70	842	8.4

a. Annual trend increase as a percent of mean AMDT, October 1969 to September 1973.

Source: Peat, Marwick, Mitchell & Co. analysis of data compiled by CALTRANS Toll Bridge Administration and Golden Gate Bridge Highway and Transportation District.

Table IV-2

SEASONAL COMPONENT OF VARIATION IN BRIDGE VEHICLE TRAFFIC
(Results of Trend-Plus-Seasonal Regressions for Period October 1969 to September 1973)

	Average Monthly Variation Above or Below Average Midweek Daily Traffic (vehicles in one direction)											
	January	February	March	April	May	June	July	August	September	October	November	December
San Francisco-Oakland Bay Bridge	-4,278	-1,468	117	920	-89	3,583	2,080	2,280	320	-559	-1,652	-1,256
Golden Gate Bridge	-3,833	-2,123	-940	-610	-577	2,089	3,898	4,307	1,379	-894	-1,355	-1,341
San Mateo-Hayward Bridge	-818	-453	-502	-205	-327	209	492	642	563	86	234	75
Richmond-San Rafael Bridge	-964	-401	-65	-32	-19	535	992	943	334	-288	-515	-516

Source: Peat, Marwick, Mitchell & Co. analysis of data compiled by CALTRANS Toll Bridge Administration and Golden Gate Bridge Highway and Transportation District.

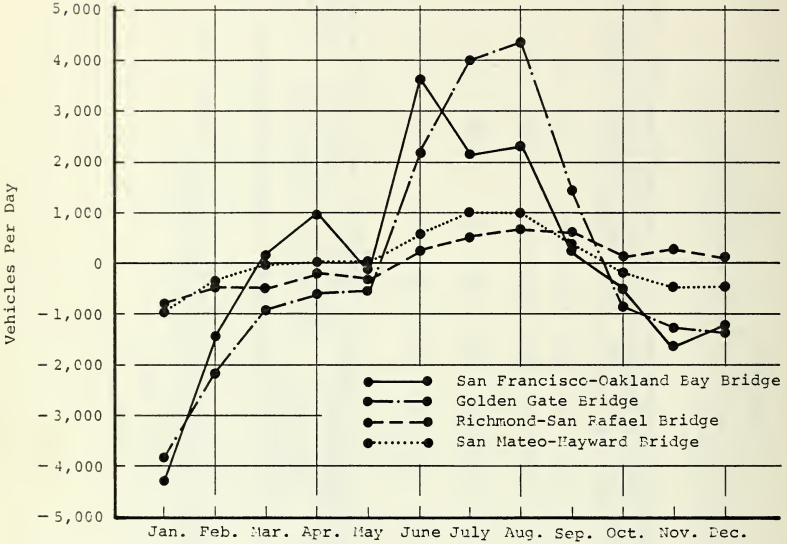

FIGURE IV-5

TYPICAL MONTHLY VARIATION IN BRIDGE TRAFFIC ABOUT TREND
FOR PERIOD OCTOBER 1969 - SEPTEMBER 1973

Source: Peat, Marwick, Mitchell & Co. Analysis of Data Compiled by CALTRANS Toll Bridge Administration and Golden Gate Bridge Highway and Transportation District.

Actual Bridge Traffic Compared to Projections

Projection of Historical Bridge Traffic Trends. To account for the underlying trend and seasonal components of traffic variation, the trend-plus-seasonal regression functions were used to "project" traffic volumes for the period from October 1973 to October 1976. These projections represent the traffic volumes which would have arisen if the trend and seasonal patterns of the previous four years had continued unchanged. In other words, the projections represent "what might have been" had factors such as BART and the gasoline crisis not disrupted travel patterns. Differences between actual traffic volumes and the values projected by the regression model represent traffic volumes which must be explained by factors other than trend and seasonal influences.

Figures IV-6, IV-7, IV-8, and IV-9 show actual and projected traffic volumes for, respectively, the San Francisco-Oakland Bay Bridge, the Golden Gate Bridge, the San Mateo-Hayward Bridge, and the Richmond-San Rafael Bridge. In each case, traffic volumes are shown from January 1972 through October 1976.* The difference between actual and projected traffic volumes from October 1973 onward is emphasized as a shaded area. These shaded areas, which represent the unexplained "shortfall" in traffic volumes, are summarized in Figure IV-10.

San Francisco-Oakland Bay Bridge Traffic. The shaded area of Figure IV-6 (also shown in Figure IV-10) clearly shows the effects of increasing gasoline prices and shortages from October 1973 onward. In the early spring of 1974 when gasoline was in shortest supply, actual traffic levels fell far below those projected. Traffic levels recovered when gasoline again became available in the early summer of 1974, but the cumulative effects of increased gasoline prices continued to depress actual traffic volumes below projected volumes in May and June. In July and August of 1974, the AC Transit strike caused Bay Bridge traffic to increase above the projected line. The difference between the projected and actual traffic volumes for September 1974 onward represents the combined effects of transbay BART service opening in mid-September and, presumably, the continuation of higher gas prices.

As illustrated in Figure IV-10, the average difference between the actual and projected traffic volumes on the Bay Bridge for the period October 1974 (the first full month of transbay BART service) through March 1975 was

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*For all four bridges, the estimated traffic volumes for January 1972 through September 1973 (the end of the period used in estimating the regression function) closely conform to actual volumes throughout the period. Thus, the trend-plus-seasonal model provides a very good explanation of aggregate traffic volumes before October 1973. This fact lends credibility to the underlying assumption of the analysis: that projection of the function forward provides a meaningful "baseline" with which to compare actual traffic levels.

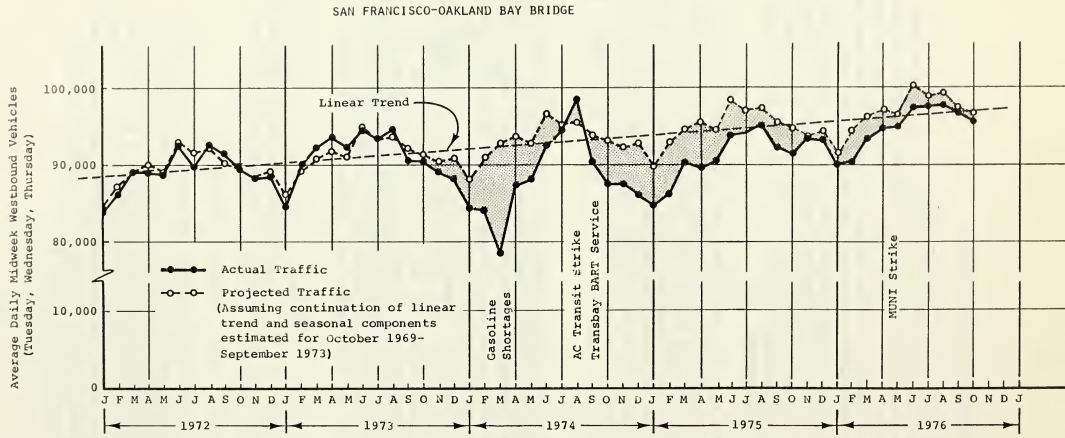

FIGURE IV-6

ACTUAL AND PROJECTED MIDWEEK TRAFFIC ON THE SAN FRANCISCO-OAKLAND BAY BRIDGE, JANUARY 1972 - OCTOBER 1976

Sources:
- CALTRANS Toll Bridge Administration, Daily Totalizer Volume Counts.
- Peat, Marwick, Mitchell & Co. Analysis.

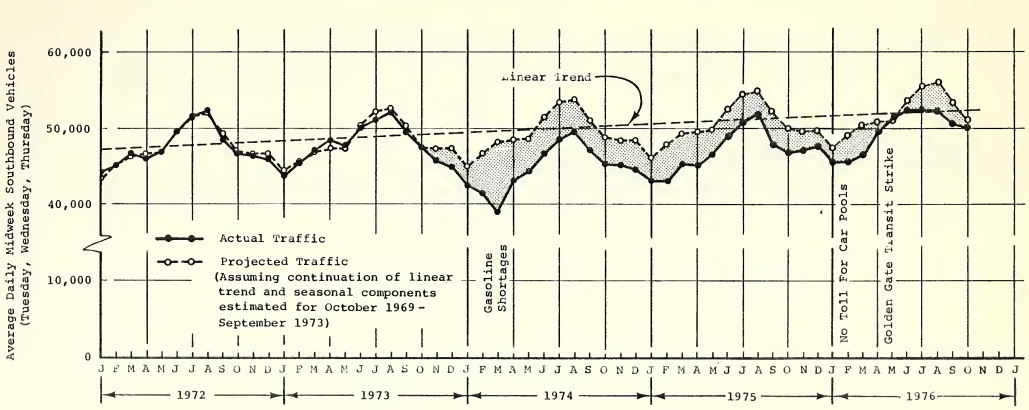

FIGURE IV-7

ACTUAL AND PROJECTED MIDWEEK TRAFFIC ON THE GOLDEN GATE BRIDGE, JANUARY 1972 - OCTOBER 1976

Sources:
- Golden Gate Bridge Highway and Transportation District, Summary Vehicle Counts.
- Peat, Marwick, Mitchell & Co. Analysis.

SAN MATEO-HAYWARD BRIDGE

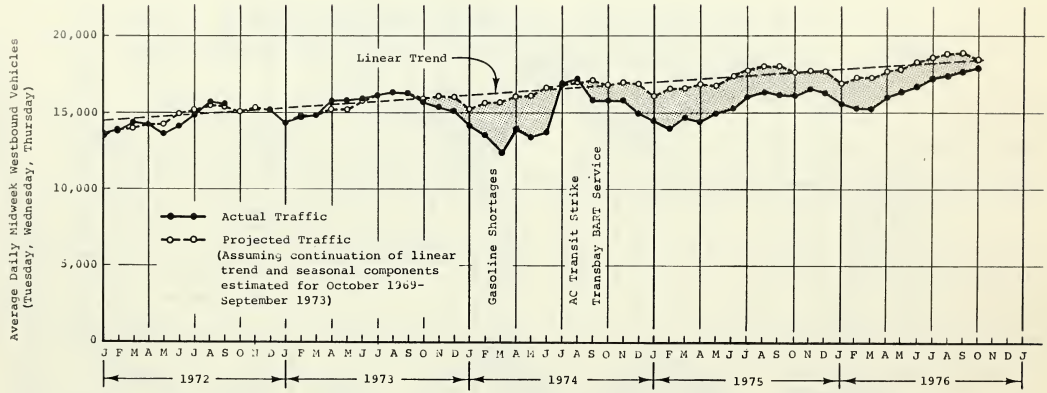

FIGURE IV-8

ACTUAL AND PROJECTED MIDWEEK TRAFFIC ON THE SAN MATEO-HAYWARD BRIDGE, JANUARY 1972 - OCTOBER 1976

Sources:
- CALTRANS Toll Bridge Administration, Daily Totalizer Volume Counts.
- Peat, Marwick, Mitchell & Co. Analysis.

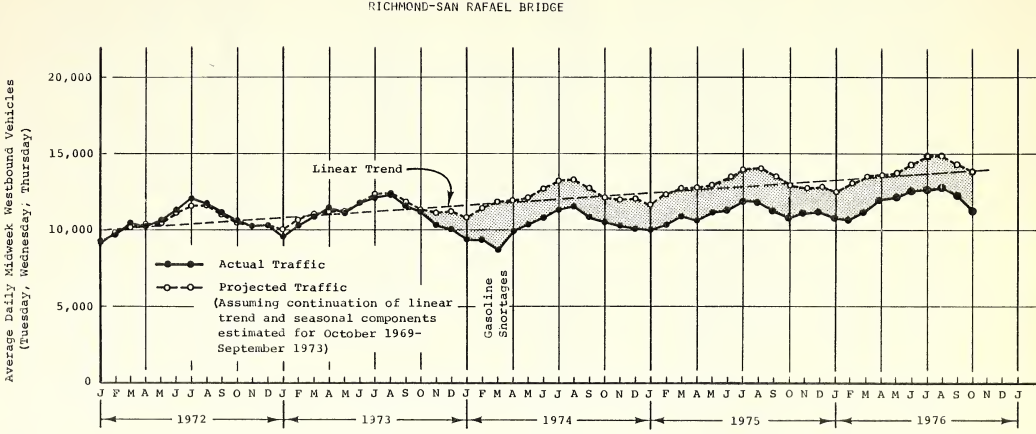

FIGURE IV-9

ACTUAL AND PROJECTED MIDWEEK TRAFFIC ON THE RICHMOND-SAN RAFAEL BRIDGE, JANUARY 1972 - OCTOBER 1976

Sources:
- CALTRANS Toll Bridge Administration, Daily Totalizer Volume Counts.
- Peat, Marwick, Mitchell & Co. Analysis.

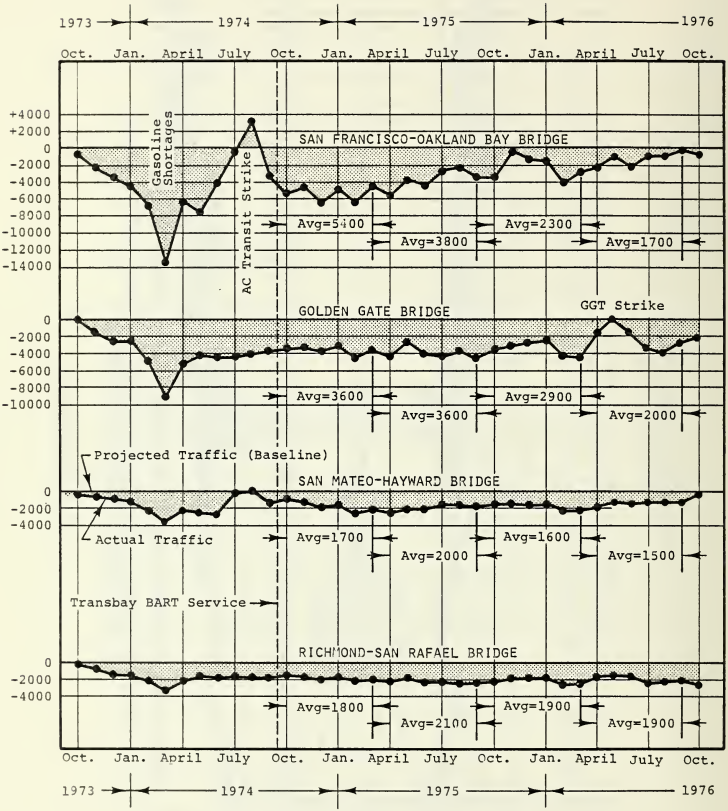

FIGURE IV-10

SHORTFALL OF TRAFFIC BELOW TREND-PLUS-SEASONAL PROJECTION
OCTOBER 1973 - OCTOBER 1976

5,400 vehicles per day. This represents a shortfall of 5.9% of the average projected value over the same six months (92,500 vehicles per day). For the next six months, April through September 1975, the shortfall was 3,800 vehicles per day or 4.0% of the average trend value over the period (96,500 vehicles per day). For the six months October 1975 through March 1976, the shortfall was 2,300 vehicles per day or 2.5% of the average trend value for the period (94,300 vehicles per day). The most recent six months illustrated in the figure, April through September 1976, show an average shortfall of 1,700 vehicles per day or 1.8% of the average trend value for the period (98,300 vehicles per day).

The extent to which diversion of travel from automobile to BART may have contributed to the shortfall (in relation to the effects of other factors) will be discussed in a later section of this chapter. It is noted here only that actual Bay Bridge traffic volumes appear to have been growing since October 1974 at a faster rate than in earlier years, so that actual traffic volumes are now about the same as those predicted by simple extrapolation of long-term growth trends.

The average 3,300-vehicle-per-day shortfall illustrated for the entire two-year period, October 1975 through September 1976, represents the net decrease in traffic resulting from the combined effects of BART, gasoline price increases, and all other factors. This shortfall is approximately twice the long-run annual growth of 1,800 vehicles per day shown in Table IV-1. Thus, relative to the baseline defined by the trend-plus-seasonal projection, the net traffic-reducing effects of BART and all other factors (averaged over the two years since transbay BART service began) is equivalent to about two years' normal historical growth in Bay Bridge traffic.

Golden Gate Bridge Traffic. Figure IV-7 shows a pattern similar to Figure IV-6 with the important exceptions that traffic volumes on the Golden Gate Bridge were unaffected by the AC Transit strike and have not been influenced by BART. The difference between the projected and actual traffic level, therefore, shows a much more regular pattern, reflecting primarily the effects of the gasoline shortage and associated price increases. From May 1974 on, the actual traffic levels follow those projected by the trend-plus-seasonal model closely, with the actual points displaced below the projected points by a nearly constant amount (except for April, May, and June 1976, when a Golden Gate Transit bus strike affected traffic levels).

Figure IV-10 illustrates that the shortfall for the six-month period October 1974 through March 1975 was 3,600 vehicles per day (7.5% of the average midweek volume of 48,100 vehicles projected for the period). For the six months, April 1975 through September 1975, the shortfall was again 3,600 vehicles (6.9% of the projected volume of 52,200 vehicles per day). For the six months, October 1975 through March 1976, the shortfall was 2,900 vehicles (5.8% of the projected volume of 49,200). In April, May, and June 1976, actual traffic volumes on the bridge were close to projected as a result of the bus strike. The four months since then show

an average shortfall of 3,000 vehicles (5.5% of the projected volume of 53,900 vehicles per day). This generally constant difference between the projected and actual volumes over the whole period is in contrast to the pattern on the Bay Bridge. The percentage differences between the projected and actual volumes for the Golden Gate Bridge are also higher than for the Bay Bridge.

San Mateo-Hayward Bridge Traffic. Figure IV-8 shows the difference between projected and actual traffic levels on the San Mateo-Hayward Bridge. A pattern very similar to the Bay Bridge is apparent. The figure clearly shows (1) the effects of the gasoline shortages in early 1974, (2) the effects of the AC Transit strike in diverting traffic from the Bay Bridge to the San Mateo Bridge, and (3) the continuing effects of increased gasoline prices and possibly BART-related traffic reductions over the final two years shown in the figure.

As with the Golden Gate Bridge, the shortfall of actual below projected traffic volumes has been fairly constant over the period from October 1974 to September 1976, averaging 1,700 vehicles per day (9.7% of the average volume of 17,500 vehicles per day projected over the two-year period). When expressed as a percentage of total traffic, the shortfall in vehicle traffic on the San Mateo-Hayward Bridge is considerably higher than the corresponding percentage shortfalls on the San Francisco-Oakland and Golden Gate Bridges.

Richmond-San Rafael Bridge Traffic. Figure IV-9 compares projected and actual traffic levels for the Richmond-San Rafael Bridge, showing a pattern very close to the Golden Gate Bridge. As with the Golden Gate Bridge, neither the AC Transit strike nor BART has affected traffic levels; the difference between projected and actual levels represents only the effects of gasoline availability and price.

Again, the shortfall of actual below projected traffic volumes is more or less constant over the two years October 1974 through September 1976, averaging 1,900 vehicles per day. This deficit represents 14.6% of the average midweek daily traffic volume over the period (13,200 vehicles), by far the highest percentage reduction of the four bridges.

Factors Changing Bridge Traffic Volumes

Six possible factors might explain the difference between actual and projected bridge traffic volumes over the period shown in Figures IV-6 through IV-10.

1. Changes in Underlying Growth Trends. The actual underlying traffic growth trends for the period from October 1973 onwards might differ from the "long-run" trends estimated for the period October 1969 through September 1973. The underlying trends could

have changed as a result of changes in overall regional economic conditions (in which case, traffic growth on all four bridges would have changed in a similar way) or as a result of differential population and economic growth patterns within the region (in which case, traffic growth would have changed in different ways on the four bridges). Also, the rate of traffic growth on the bridges could have been constrained (in different ways) by their traffic-carrying capacities.

2. Changes in Seasonal Patterns. The actual seasonal variation in traffic volumes could have changed since the 1969-1973 period used in estimating the trend-plus-seasonal model. Any such changes would probably be similar on all four bridges (although the higher proportions of tourist traffic on the Golden Gate and San Francisco-Oakland Bridges could cause different changes in seasonal patterns).

3. Gasoline Price Increases. The gasoline shortages of early 1974 and the associated increase in gasoline prices (illustrated in Figure I-1) probably reduced traffic volumes of the four bridges in similar ways, although some differential impacts could result as a function of the purpose of travel. (For example, journey-to-work travel is generally less price elastic than travel for non-work purposes so that the higher the proportion of commute travel in the total, the less might be the expected impacts of gas price increases.)

4. BART. The start of transbay BART service in September 1974 was expected to have major automobile traffic-reducing effects on the San Francisco-Oakland Bay Bridge. Some minor impacts might also be expected on the San Mateo-Hayward Bridge as a result of Fremont-San Francisco travel diverting from automobile. There is no reason to expect significant BART impacts for the Golden Gate or Richmond-San Rafael Bridges.

5. Induced or Diverted Traffic. Reductions in vehicle traffic volumes caused by diversion of travel to BART (or any other reason) could lessen traffic congestion and thereby cause new automobile trips (which would otherwise not have been made, would have been made to other destinations, or would have been made by different routes). For example, a shift of San Francisco-bound traffic from the San Mateo-Hayward to the San Francisco-Oakland Bridge might take place if the latter's congestion were reduced. Any effect of this type is likely to be a function of the change in volume relative to the capacity characteristics of the bridges (i.e., a given [initial] reduction in traffic is more likely to give rise to induced traffic on a highway which was previously operating at close to capacity than on one which was not).

6. Other Factors. Among other factors causing changes in bridge traffic volumes, the AC Transit strike of July and August 1974 clearly had a major impact on Bay Bridge traffic and a lesser impact on San Mateo-Hayward Bridge traffic. The Golden Gate and Richmond-San Rafael Bridges were not affected. However, automobile traffic volumes on the Golden Gate Bridge were affected by a strike of Golden Gate Transit District employees from April to June 1976. San Francisco-Oakland Bay Bridge traffic volumes may also have been affected in April and May 1976 by a strike of San Francisco city workers which shut down MUNI.

Comparison of Traffic Changes among Bridges

The fact that the differences between the actual and projected traffic volumes on the four bridges have remained fairly constant from October 1973 onwards (especially on the Golden Gate, San Mateo-Hayward, and Richmond-San Rafael Bridges) suggests that the slopes of the trend lines and the month-to-month patterns of seasonal variation estimated for the period 1969 to 1973 have remained stable since transbay BART began service. This, in turn, suggests that the effects of factors 1 and 2 listed in the previous sections may be small and that (within the two-year time frame considered) the trend-plus-seasonal model's projections provide a reasonable basis for explaining changes in bridge traffic volumes in terms of the other four factors listed. The remainder of this section analyzes the difference between actual traffic volumes and those projected by the trend-plus-seasonal models. (This difference is referred to below as a "reduction" in traffic volumes, although more strictly it is a deficit or shortfall.)

Table IV-3 summarizes the analysis of average daily midweek traffic on the four bridges across San Francisco Bay. The table shows (1) average daily midweek traffic volumes projected from the trend-plus-seasonal model for the two-year period from October 1974 (immediately after the start of transbay BART service) through September 1976; (2) the average actual daily midweek traffic volume for the same two years; (3) the difference between the projected and actual volumes; (4) this difference (reduction) expressed as a percentage of the projected level; and (5) the slope of the long-run trend in traffic growth (i.e., the growth rate estimated in the trend-plus-seasonal model). This slope is estimated as a percentage of the average traffic over the 48 months from October 1969 through September 1973. Finally, the table gives the number of traffic lanes in each direction on the bridges and the average daily volumes divided by the number of lanes. The latter figures form crude measures of the volume-to-capacity characteristics of the bridges.

Of the four bridges, the opening of transbay BART service was expected to have major impacts on the San Francisco-Oakland Bay Bridge. But in fact, the total reduction in average daily traffic on the Bay Bridge shown in Figure IV-3 (3,300 vehicles per day) is the same as the reduction on the

Table IV-3

SUMMARY OF ACTUAL AND PROJECTED AVERAGE DAILY MIDWEEK BRIDGE TRAFFIC[a]

	San Francisco-Oakland Bay Bridge	Golden Gate Bridge	San Mateo-Hayward Bridge	Richmond-San Rafael Bridge
Average Projected Daily Traffic October 1974-September 1976	95,400	50,600	17,500	13,200
Average Actual Daily Traffic October 1974-September 1976	92,100	47,300	15,800	11,300
Difference (Projected-Actual)	3,300	3,300	1,700	1,900
Difference as Percentage of Projected	3.5%	6.5%	9.7%	14.6%
Slope of Long-Run Trend in Traffic Growth	2.0%	2.4%	6.0%	8.4%
Number of Traffic Lanes in Each Direction	5	3[b] (or 4)	2[c] (or 3)	3
Average Daily Traffic per Lane	18,400	15,800 (or 11,800)	7,900 (or 5,300)	3,800

a. See accompanying text for explanation of traffic projections.
b. The six lanes of the Golden Gate Bridge can either carry three lanes in each direction, or four lanes in one direction and two in the other.
c. The San Mateo-Hayward Bridge has two lanes in each direction on the approach causeways and three in each direction on the main span.

Source: Peat, Marwick, Mitchell & Co. analysis of traffic counts compiled by CALTRANS, Toll Bridge Administration, and Golden Gate Bridge Highway and Transportation District.

Golden Gate Bridge. Expressed as a percentage of total traffic, the reduction on the Bay Bridge (3.5%) is by far the smallest of the four bridges.* As discussed earlier, these reductions represent the sum of several influences in addition to BART--in particular, gasoline prices and the possible effects of induced traffic.

Effects of Increased Gasoline Prices. The analyses presented earlier show that a marked decrease in highway traffic has coincided with increasing gasoline prices, and it seems reasonable to assume a direct cause-and-effect relationship between the two. However, the form of this relationship is not obvious. The elasticity of highway travel with respect to gasoline price is probably a function of the purpose of travel--with "essential" travel such as work trips being less elastic than "nonessential" trips such as recreational trips. This may explain in part, why the percentage reductions of traffic on the San Mateo-Hayward and Richmond-San Rafael Bridges are larger than for the Bay Bridge and the Golden Gate Bridge, since the former two carry a smaller proportion of commuter traffic than the latter two bridges. It is also likely that travel by high-income travelers is less elastic than travel by low-income travelers. Gasoline prices also vary slightly in different parts of the BART impact area. These factors may all contribute to differential effects of gasoline price on traffic volumes on the four bridges.

Effects of Induced or Diverted Traffic. The data presented in Table IV-3 do not allow any definite conclusion to be drawn; however, a large part of the differences between the percentage traffic reductions for the four bridges might be explained by the effects of induced traffic. Table IV-3 shows (1) a positive correlation between the percentage reduction of actual traffic below projected traffic and the slope of the trend line, and (2) an inverse correlation between the percentage reduction in traffic and the average daily traffic per lane.

Both these relationships point to the fact that the reduction in traffic has been proportionately smallest for those bridges on which the daily traffic volume is closest to capacity (and on which, therefore, the growth rate may have been slowed by capacity constraints). The data are also consistent with the hypothesis that the reductions in traffic caused by BART and gasoline

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*As shown in Figure IV-10 (and discussed earlier), the difference between projected and actual traffic levels for the Bay Bridge appears to have decreased over the two years (October 1974 to September 1976). If only the six months following the start of transbay BART service are analyzed (instead of the two years summarized in Table IV-3), a slightly different picture emerges: the difference between projected and actual traffic volumes for the six months is 5,400 vehicles per day (5.9% of the total projected). But even this higher figure does not change the conclusion that the percentage reduction in traffic on the Bay Bridge is the smallest of all four bridges.

price increases (or gasoline price increases alone) have given rise to reductions in traffic congestion--which, in turn, have effectively relaxed the capacity constraints and induced previously suppressed trips to be made more frequently or diverted trips from other destinations and routes.

For example, on the Richmond-San Rafael Bridge where traffic volumes were well below capacity, congestion levels probably suppressed traffic very little, if at all. The 15% reduction in traffic levels, therefore, represents only the traffic-reducing effects of the rise in gasoline prices. In contrast, on the Bay Bridge where traffic volumes were previously very heavy over long periods of the day, the net reduction of 3% in traffic volumes may reflect a reduction due to increased gasoline prices and BART offset by an increase due to induced travel. The corresponding percentage reductions of 7% and 10% on the Golden Gate Bridge and the San Mateo-Hayward Bridge, respectively, are also consistent with the respective volume-to-capacity characteristics of these two bridges.

Clearly, many uncertainties are associated with this analysis--especially with regard to the "induced traffic" argument. The following section attempts to shed more light on Bay Bridge vehicle volumes and the relative effects of BART, gasoline price increases, induced travel, and other factors.

Regression Analyses

Regression analyses were performed on data for each of the four bridges. In each case, the dependent variable is the difference between the actual average daily midweek traffic volume and the volume projected by the trend-plus-seasonal model (the "traffic reduction"). These variables represent the changes in traffic volumes not explained by long-run trend and seasonal variations (i.e., the shaded areas shown in Figures IV-6, IV-7, IV-8, IV-9, and IV-10). The dependent variables are defined as projected minus actual so that positive values represent reductions in traffic volumes below those projected.

Explanatory variables are defined as follows:

Variable Name	Definition
1. Gasoline Price	Average retail price per gallon for regular gasoline in the San Francisco-Oakland SMSA expressed in constant 1967 prices (as shown and documented in Figure I-3).
2. Gasoline Shortage	Dummy variable identifying the period over which gasoline availability was restricted (January, February, and March 1974).

3.	AC Transit Strike	Dummy variable identifying the period of the AC Transit strike (July and August 1974).
4.	Transbay BART Ridership	Average weekday one-way trans-bay BART ridership. (Source: BART Monthly Patronage Reports.)
5.	Golden Gate Transit Strike	Dummy variable identifying the period of the Golden Gate Transit strike (April, May, and June 1976).

In each case, the regressions were run on monthly data for the period October 1973 (the start date for the trend-plus-seasonal projections) through October 1976. These data are presented in Table IV-4.

The explanatory variables investigated in each of the regressions are as follows:

Bridge	Gasoline Price	Gasoline Shortage	AC Transit Strike	Golden Gate Transit Strike
San Francisco-Oakland	x	x	x	
Golden Gate	x	x		x
San Mateo-Hayward	x	x	x	
Richmond-San Rafael	x	x		

Tables IV-5, IV-6, IV-7, and IV-8 detail the results of the regressions, with only those explanatory variables having a statistically significant coefficient included in each regression.

As indicated by the R^2 statistics (ranging from 0.63 to 0.44), all four regression models explain a significant part of the variance in the dependent variable. The R^2 statistics may not appear very high; but it must be remembered that the dependent variables in the regressions are themselves the unexplained residuals of the simple trend-plus-seasonal model regressions. If the two models are taken together, a convincing explanation of total vehicle traffic volumes is achieved. This is illustrated in Figure IV-11, which compares the actual traffic volumes on the San Francisco-Oakland Bay Bridge from October 1973 through October 1976 with the volumes forecast by combining trend-plus-seasonal forecasts with forecasts of traffic reductions derived from the "residual" regression model. Figure IV-11 shows that, with the exception of the first three months of 1974 (when gasoline was in short supply), forecast traffic volumes are fairly close to actual

Table IV-4

INPUT DATA FOR REGRESSION ANALYSES OF BRIDGE TRAFFIC REDUCTIONS

Month/Year	Dependent Variables--Traffic Reductions on: San Francisco-Oakland	Golden Gate	San Mateo-Hayward	Richmond-San Rafael	Explanatory Variables: Gasoline Price (cents)	Gasoline Shortage	AC Transit Strike	Transbay BART Ridership	Golden Gate Transit Strike
October 1973	909	- 70	337	109	31.3¢	0	0	0	0
November	1,327	1,359	717	780	32.2	0	0	0	0
December	2,514	2,322	995	1,219	33.2	0	0	0	0
January 1974	3,485	2,354	1,128	1,399	34.6	1	0	0	0
February	6,914	4,952	2,162	2,024	36.0	1	0	0	0
March	13,990	9,009	3,214	3,237	37.9	1	0	0	0
April	6,314	5,226	2,157	2,027	37.9	0	0	0	0
May	7,810	4,098	1,557	1,629	39.2	0	0	0	0
June	4,043	4,411	1,849	1,854	39.2	0	0	0	0
July	744	4,452	63	1,751	39.5	0	1	0	0
August	-3,080	4,005	1	1,715	38.8	0	1	0	0
September	3,316	3,815	1,384	1,770	38.0	0	0	21,361	0
October	5,437	3,389	990	1,594	36.7	0	0	25,954	0
November	4,711	3,122	1,213	1,700	36.5	0	0	27,192	0
December	6,584	3,724	1,986	1,987	36.2	0	0	28,075	0
January 1975	4,992	3,038	1,631	1,666	36.3	0	0	26,170	0
February	6,503	4,734	2,604	2,002	35.9	0	0	25,254	0
March	4,356	3,706	2,023	1,923	36.0	0	0	25,635	0
April	5,837	4,268	2,480	2,142	36.5	0	0	25,928	0
May	3,987	2,852	2,000	1,799	36.6	0	0	26,333	0
June	4,505	3,475	2,043	2,125	37.2	0	0	27,180	0
July	2,886	3,705	1,757	2,096	38.1	0	0	25,568	0
August	2,318	3,208	1,651	2,164	38.5	0	0	27,410	0
September	3,397	4,202	1,828	2,253	38.1	0	0	28,327	0
October	3,443	3,126	1,461	2,029	37.9	0	0	27,525	0
November	570	2,485	1,239	1,607	37.5	0	0	24,648	0
December	1,297	2,302	1,406	1,603	37.1	0	0	27,548	0
January 1976	1,646	1,881	1,268	1,593	36.8	0	0	25,345	0
February	4,067	3,571	2,032	2,333	36.4	0	0	25,603	0
March	2,874	3,905	2,042	2,290	35.6	0	0	25,347	0
April	2,332	1,231	1,763	1,604	35.7	0	0	24,788	1
May	1,536	- 394	1,407	1,609	35.3	0	0	25,372	1
June	2,823	1,460	1,670	1,811	35.8	0	0	27,415	1
July	1,436	3,215	1,441	2,217	36.4	0	0	27,550	0
August	1,456	3,801	1,443	2,134	36.7	0	0	28,133	0
September	837	2,829	1,226	2,038	37.0	0	0	27,338	0
October	1,113	2,031	627	2,581	36.8	0	0	26,564	0

Note: See accompanying text for definition and sources of variables.

Table IV-5

REGRESSION SUMMARY
San Francisco-Oakland Bay Bridge

Dependent Variable:[a] Traffic Reduction October 1973-October 1976[b]

Explanatory Variable[a]	Coefficient[c]	t-statistic
Gasoline Price (in cents)	543	2.49
Gasoline Shortage	4,972	3.81
AC Transit Strike	5,946	3.55

Intercept: -16,479

Coefficient of Multiple Determination: $R^2 = 0.47$

Correlation among Variables:

	Traffic Reduction	Gasoline Price	Gasoline Shortage	AC Transit Strike	BART Ridership
Traffic Reduction	1.00	0.13	0.49	-0.40	-0.13
Gasoline Price	0.13	1.00	-0.08	0.35	0.11
Gasoline Shortage	0.49	-0.08	1.00	-0.07	-0.45
AC Transit Strike	-0.40	0.35	-0.07	1.00	-0.37
BART Ridership	-0.13	0.11	-0.45	-0.37	1.00

a. See accompanying text for definition of variables.
b. See Figure IV-6.
c. All coefficients are significantly different from zero at the 2% level.

Table IV-6

REGRESSION SUMMARY
Golden Gate Bridge

Dependent Variable:[a] Traffic Reduction October 1973-October 1976[b]

Explanatory Variable[a]	Coefficient[c]	t-statistic
Gasoline Price (in cents)	486	4.96
Gasoline Shortage	2,440	3.96
Golden Gate Transit Strike	-1,941	3.11

Intercept: -14,580

Coefficient of Multiple Determination: $R^2 = 0.63$

Correlation among Variables:

	Traffic Reduction	Gasoline Price	Gasoline Shortage	Golden Gate Transit Strike
Traffic Reduction	1.00	0.56	0.41	-0.47
Gasoline Price	0.56	1.00	-0.08	-0.18
Gasoline Shortage	0.41	-0.08	1.00	-0.09
Golden Gate Transit Strike	-0.47	-0.18	-0.09	1.00

a. See accompanying text for definition of variables.
b. See Figure IV-7.
c. All coefficients are significantly different from zero at the 1% level.

Table IV-7

REGRESSION SUMMARY
San Mateo-Hayward Bridge

Dependent Variable:[a] Traffic Reduction October 1973-October 1976[b]

Explanatory Variable[a]	Coefficient[c]	t-statistic
Gasoline Price (in cents)	154	3.12
Gasoline Shortage	653	2.20
AC Transit Strike	-1,944	5.11

Intercept: -4,068

Coefficient of Multiple Determination: $R^2 = 0.51$

Correlation among Variables:

	Traffic Reduction	Gasoline Price	Gasoline Shortage	AC Transit Strike	BART Ridership
Traffic Reduction	1.00	0.15	0.29	0.55	0.25
Gasoline Price	0.15	1.00	-0.08	0.35	0.11
Gasoline Shortage	0.29	-0.08	1.00	-0.07	-0.45
AC Transit Strike	-0.55	0.35	-0.07	1.00	-0.37
BART Ridership	0.25	0.11	-0.45	-0.37	1.00

a. See accompanying text for definition of variables.
b. See Figure IV-8.
c. All coefficients are significantly different from zero at the 3% level.

Table IV-8

REGRESSION SUMMARY
Richmond-San Rafael Bridge

Dependent Variable:[a] Traffic Reduction October 1973-October 1976[b]

Explanatory Variable[a]	Coefficient[c]	t-statistic
Gasoline Price (in cents)	178	4.85
Gasoline Shortage	494	2.11

Intercept: -4,711

Coefficient of Multiple Determination: $R^2 = 0.44$

Correlation among Variables:

	Traffic Reduction	Gasoline Price	Gasoline Shortage
Traffic Reduction	1.00	0.60	0.22
Gasoline Price	0.60	1.00	-0.08
Gasoline Shortage	0.22	-0.08	1.00

a. See accompanying text for definition of variables.
b. See Figure IV-9.
c. Both coefficients are significantly different from zero at the 4% level.

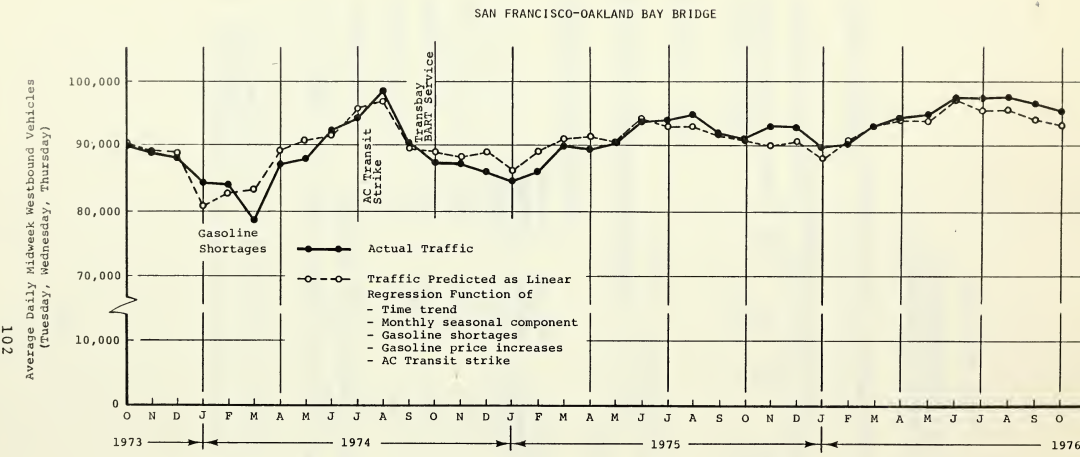

FIGURE IV-11

COMPARISON OF ACTUAL AND REGRESSION FORECASTS OF AVERAGE DAILY MIDWEEK TRAFFIC ON THE SAN FRANCISCO-BAY BRIDGE OCTOBER 1973-OCTOBER 1976

Source: Peat, Marwick, Mitchell & Co. Analysis of Data
Compiled by CALTRANS Toll Bridge Administration

volumes over the whole forecast period (especially considering that the forecasts extend three years out). Over the period shown, the average (absolute) difference between actual and forecast traffic is only 1,700 vehicles per day or 1.8% of the average daily vehicle volume on the bridge.

As shown on Tables IV-5 through IV-8 the coefficients for gasoline shortage and gasoline price are all significant and of the "correct" sign. The effects of the AC Transit and Golden Gate Transit strikes are also accounted for significantly. However, in neither the Bay Bridge nor San Mateo Bridge equation does BART ridership enter as a significant variable.

Gasoline Shortage. The coefficient for the gasoline shortage variable implies that the limited availability of gasoline in January, February, and March 1974 reduces bridge traffic by the following amounts: San Francisco-Oakland Bay Bridge, 4,972 vehicles per day (5.2% of average total daily traffic); Golden Gate Bridge, 2,440 vehicles per day (4.8%); San Mateo-Hayward Bridge, 653 vehicles per day (3.7%); and Richmond-San Rafael Bridge, 494 vehicles per day (3.7%). Bearing in mind the estimating errors inherent in the coefficients, the percentage traffic reductions are remarkably similar for the four bridges.

Gasoline Price. On the San Francisco-Oakland Bay Bridge the coefficient for gasoline price implies that a $0.01 increase in gasoline price (at 1967 prices) produces a traffic volume decrease of 540 vehicles per day or 0.6% of the total traffic volume. On the Golden Gate Bridge, the corresponding reduction is 490 vehicles or 1.0% of the total. On the San Mateo-Hayward Bridge, the regression coefficient implies that a $0.01 gas price increase produces a reduction of 150 vehicles per day (0.9%), and on the Richmond-San Rafael Bridge a reduction of 180 vehicles per day (1.3%). Again, bearing in mind inherent estimating errors, the coefficient values are similar for all four bridges when expressed as a percentage of the total traffic volume.

As shown in Figure I-3, since the early spring of 1974, gasoline prices have not changed very much (especially when expressed in 1967 dollars), ranging between a high of $0.39 and a low of $0.35. This is consistent with the earlier observation that actual traffic levels, especially on the two bridges unaffected by BART, (i.e., the Golden Gate and Richmond-San Rafael Bridges), have remained below the trend-plus-seasonal projections of traffic by a fairly constant amount.

The average price of gasoline over the two-year period October 1971 to September 1973 was $0.285 and over the two-year period October 1974 to September 1976 was $0.367 per gallon (all prices expressed in 1967 dollars). Multiplying the difference between these two averages, $0.082, by each of the four gasoline price coefficients gives the following estimates of bridge traffic volume reductions attributable to the rise in gasoline prices: San Francisco-Oakland Bay Bridge, 4,463 vehicles per day; Golden Gate Bridge, 3,995 vehicles per day; San Mateo-Hayward Bridge, 1,266 vehicles per day; and Richmond-San Rafael Bridge, 1,463 vehicles per day.

AC Transit and Golden Gate Transit Strikes. The regression coefficients for the variables representing the AC Transit strike in July and August 1974 imply that traffic increased by 5,950 vehicles per day on the San Francisco-Oakland Bay Bridge as a result of the strike and by 1,940 vehicles per day on the San Mateo-Hayward Bridge.* The regression coefficient for the variable representing the Golden Gate Transit strike in April, May, and June 1976 suggests that the strike increased Golden Gate Bridge traffic by about 1,940 vehicles per day.

BART Ridership. In neither the Bay Bridge nor the San Mateo-Hayward Bridge regression equation does transbay BART ridership appear as a statistically significant explanatory variable. Thus, the regression model allows nothing conclusive to be said about the effects of BART on aggregate Bay Bridge traffic. This is not to say that BART had no effect on bridge traffic, but the data do not allow the effects of BART starting service to be separated from the effects of other factors, particularly the gasoline shortages and the AC Transit strike, since these three events all occurred within a relatively short time. (This is illustrated by the relatively high correlation coefficients between BART ridership and the other explanatory variables shown in Table IV-5.)

The above regression analyses of aggregate vehicle volumes tend to confirm the simpler analyses of the previous section with regard to the effects of gasoline availability and price on bridge traffic volumes, but allow no more definite conclusions to be drawn. In the context of these other factors, BART's impacts on traffic volumes appear to be small and are extremely difficult to detect.

Single-Stage Regression Versus Two-Stage Regression. The analyses of the preceding sections attempt to infer the relative influences of BART, gasoline prices, etc., on the bridge traffic volumes by a two-stage regression procedure; the second-stage regression being performed on data that are corrected for trend and seasonality as estimated in the first stage. This two-stage regression procedure could be argued as inappropriate in that the coefficients of the model are not estimated simultaneously, and hence, do not provide a true least-squares solution for the variables considered. However, even though stagewise regression provides biased estimates, it is a commonly used and more suitable procedure in situations where trend and seasonal effects are present in the data.**

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*The high correlation shown in Tables IV-5 and IV-7 between gasoline price and the AC Transit strike variable is presumably fortuitous, not causative.

**See N. R. Draper and H. Smith, Applied Regression Analysis, John Wiley & Sons, Inc., New York, 1966, pp 173-177 and pp 309-316 for a discussion of stagewise regression and for several examples of its use in analyzing economic time series, including instances in which the stagewise procedure yields lower mean square errors than the single-stage least-squares procedure under certain conditions.

An advantage of the stagewise regression is that variables can be entered in such a way that the expected direction of effects can be preserved. A straightforward least-squares equation does not always achieve this due to correlations between the variables and is thus an unsuitable method if one wishes to isolate the effects of specific variables.*

Since the purpose of our analysis is to study the effects of BART (in particular) and gasoline shortages, etc., on bridge traffic, it is necessary to isolate their effects from those of trend and seasonal factors. Only data up to September 1973 are used in a first-stage regression for estimating trend and seasonal effects, because they provide the basis for a more stable and meaningful estimate of the true underlying trend and seasonal components of traffic growth than do later data which include disruptive influences such as the "gasoline crisis," transit strikes, etc.

To assess whether the two-stage procedure gives substantially different results from the single-stage regression solution, the actual average daily midweek traffic volume on the Bay Bridge was regressed simultaneously against all the explanatory variables included previously in the two-stage regression. Since the two regressions are estimated for slightly different data sets (i.e., data on gasoline prices from 1969 to 1973 are included in the single-stage, but not the two-stage regression), they are not strictly comparable. However, as shown in Table IV-9, the results of the single-stage regression generally agree with the results of the two-stage procedure (summarized in Tables IV-1 and IV-5). The same variables appear significant in the two models, and, importantly, the BART ridership variable is not significant in either model. Thus, differences between the results of the single-stage and two-stage models are not great. Certainly, these differences do not change the conclusions regarding BART's effects.

Caldecott Tunnel Traffic

The Caldecott Tunnel is a critical section on Route 24 which closely parallels the BART Concord Line and is a major connection to the Bay Bridge. Figure IV-12 plots historical highway traffic volumes through the tunnel. The data shown are 14-hour (6:00 a.m. to 8:00 p.m.) midweek daily westbound volumes as collected by the University of California ITS semiannual

*The high positive correlation between gasoline price and traffic volume shown in Table IV-9 is an illustration. This correlation arises because both variables increased with time over the period from October 1969 to October 1976 as a whole, not because of any cause-and-effect relationship. In contrast, the correlation coefficient between gasoline price and traffic reduction shown in Table IV-5 (for the period October 1973 to October 1976) used in the second-stage regression is of the "correct" sign and reflects the true influence of gasoline price increases on reducing traffic volume.

Table IV-9

REGRESSION SUMMARY
San Francisco-Oakland Bay Bridge
(Single-Stage Regression)

Dependent Variable:[a] Average Daily Midweek Traffic October 1969-October 1976[b]

Explanatory Variable[a]	Coefficient[c]	t-statistic
Linear Trend (per month)	135	12.64
Gasoline Price (in cents)	- 347	- 4.93
Gasoline Shortage	-5,111	- 4.80
AC Transit Strike	4,551	3.39
Monthly Seasonal Effect	--[d]	--[d]

Intercept: 93,675

Coefficient of Multiple Determination: $R^2 = 0.86$

Correlation among Variables:

	Traffic Volume	Linear Trend	Gasoline Price	Gasoline Shortage	AC Transit Strike	BART Ridership
Traffic Volume	1.00	0.63	0.27	-0.33	0.27	0.43
Linear Trend	0.63	1.00	0.70	0.08	0.10	0.80
Gasoline Price	0.27	0.70	1.00	0.17	0.26	0.70
Gasoline Shortage	-0.33	0.08	0.17	1.00	-0.03	-0.13
AC Transit Strike	0.27	0.10	0.26	-0.03	1.00	-0.10
BART Ridership	0.43	0.80	0.70	-0.13	-0.10	1.00

a. See accompanying text for definition of variables.
b. See Figure IV-1.
c. All coefficients shown are significantly different from zero at the 1% level.
d. Also entered into the equation (but not shown here) were dummy variables representing the seasonal influences associated with each of the 12 months of the year. These are defined in the same way as in the "trend-plus-seasonal" model described at the beginning of the chapter.

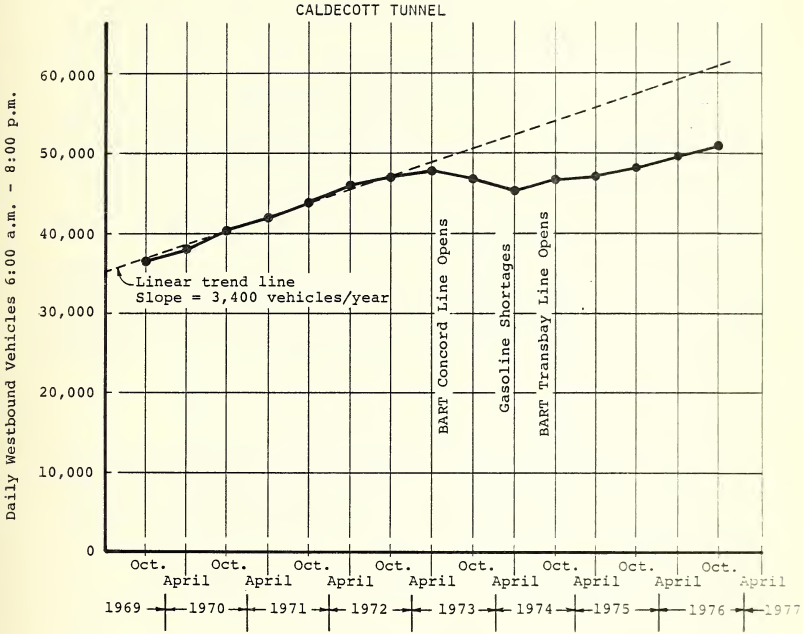

FIGURE IV-12

DAILY TRAFFIC THROUGH THE CALDECOTT TUNNEL
OCTOBER 1969 - OCTOBER 1976

Source: University of California, Institute of Transportation Studies

travel surveys. Traffic through the Caldecott Tunnel increased steadily from October 1969 to April 1973, just before the opening of the BART Concord Line. The rate of increase in 14-hour westbound midweek traffic was about 3,400 vehicles per year. This represents an annual increase of 8.0% of the mean traffic volume over the same period (42,500 vehicles per day). The traffic volume decreased when BART's Concord Line opened. Based on the limited data collected in October of 1973 (just before the oil embargo and the ensuing gasoline shortage), a drop of some 3,500 westbound vehicles per 14-hour day appeared. A further decrease occurred when gasoline became scarce and more expensive. By April 1974, actual traffic volume was about 7,000 vehicles (or 13.5%) below the level projected by extrapolation of the linear trend line, due to a combination of BART Concord Line service, the gasoline shortage, and higher gasoline prices. When gasoline became more available, highway traffic started to increase again, apparently following a slightly flatter trend than before.

Clearly, assessing the effect of the opening of BART transbay service with any confidence is not possible given the limited data shown in Figure IV-12 and the other factors involved, but the equivalent of no more than a one-year shift in the long-term trend is indicated as probably attributable to BART. Data on total travel through the tunnel by automobile, bus, and BART are analyzed in Chapter V.

Other Highway Traffic

A limited amount of pre-BART and post-BART highway traffic volume data are available for other selected locations in the Bay Area. Table IV-10 lists these locations and inventories available, potentially useful data. Unfortunately, comparing these data does not allow any meaningful conclusions about BART's impact on highway traffic volumes for the following reasons:

- Since pre-BART and post-BART count periods are typically over two years apart, changes in traffic volumes have been caused by many factors in addition to BART. (See Table I-1.)

- Sample sizes are too small (typically only about four observations) to lend much statistical significance to the comparisons. In addition, variances for the pre-BART and post-BART samples are quite different in some cases.

- For one location shown in Table IV-10 (Route 80), the pre-BART and post-BART counts were taken using different procedures. (The former was done manually and the latter using mechanical counters.)

Table IV-10

INVENTORY OF HIGHWAY TRAFFIC COUNTS

Route and Location	Parallel BART Line	Count Directions	Count Method	Dates
I-80, south of Powell Street	Richmond	Both	Manual	10/19/72, 10/25/72, 11/9/72
			Machine	5/15/75-5/30/75
Route 24, east of Caldecott Tunnel	Concord	Both	Machine	10/18/72-10/27/72
				4/11/74-4/25/74
I-580 at 106th Avenue	Fremont	Both	Machine	6/5/72-6/8/72
				6/8/72-6/16/72
				5/13/75-5/20/75
Route 101, south of Brisbane	Daly City	Northbound Only	Machine	5/14/74-5/22/74
				5/23/75-5/28/75

- In some cases, traffic counts were taken in different months of the year, thereby introducing seasonal variations to the comparison.

- For one location (Route 580), the pre-BART and post-BART counts were taken at different locations; the former at on- and off-ramps, and the latter on Route 580 itself.

For these reasons, no attempt was made to analyze these traffic volume counts beyond summarizing the data in Table IV-11.

Table IV-11

SUMMARY OF PRE-BART AND POST-BART TRAFFIC VOLUME DATA

Route and Location	Direction	Pre-BART Daily Traffic Volume Sample Size	Pre-BART Daily Traffic Volume Mean	Pre-BART Daily Traffic Volume Standard Deviation	Post-BART Daily Traffic Volume Sample Size	Post-BART Daily Traffic Volume Mean	Post-BART Daily Traffic Volume Standard Deviation
I-80, south of Powell Street	Northbound	3	31,600	223	5	34,800	1,095
	Southbound	3	36,400	975	5	30,510	4,393
Route 24, east of Caldecott Tunnel	Westbound	5	52,500	634	7	50,000	822
	Eastbound	5	44,500	4,776	7	49,200	1,028
I-580 at 106th Avenue[a]	Northbound	4	4,900	174	2	23,200	409
	Southbound	5	5,000	138	3	24,500	618
Route 101, south of Brisbane	Northbound	2	34,670	57	1	25,800	--

a. Pre-BART data were collected at the on-ramp and off-ramp; post-BART data were collected on Route 580 itself.

V. CHANGES IN TOTAL TRAVEL VOLUMES

Travel in the San Francisco-Oakland Corridor

The previous chapter considers only aggregate 24-hour vehicle traffic volumes. More meaningful analyses of the impacts of transbay BART on travel in the San Francisco-Oakland Bay Bridge corridor must (1) concentrate on the 14-hour period when BART operates,* and (2) consider total passenger travel by bus, BART, and private automobile.

Distribution of Passenger Trips by Mode and by Time of Day. Figure V-1 shows the distribution of westbound passenger trips in the San Francisco-Oakland Bay Bridge corridor between 6:00 a.m. and 8:00 p.m. as shown in the October 1975 survey by the University of California ITS. Excluded are person-trips in commercial vehicles other than buses and BART. (Typically, trips in trucks represent between 7% and 8% of total trips.)

During the morning peak hours, a majority (about 55%) of all person-trips are made by transit--divided about equally between bus and BART. In the off-peak hours, the automobile is the dominant mode of travel, carrying about 80% of total off-peak person-trips during the daytime and over 90% of total person-trips after sunset. After the morning peak, the proportion of westbound trips carried by transit decreases fairly steadily except for a small increase during the afternoon peak. Note that during the off-peak period, the split of transit trips between bus and BART remains fairly constant.

Projections of Historical Trend. Figure V-2 shows midweek daily westbound passenger travel in the San Francisco-Oakland Bay Bridge corridor in the 14 hours from 6:00 a.m. to 8:00 p.m. (the hours of BART operation until late November 1975). Included in these data are trips by persons in private automobiles, in AC Transit and Greyhound buses across the bridge, and on transbay BART.

Long-term trend and seasonal components of travel are apparent from the graphs of total trips, automobile trips, and transit trips across the Bay Bridge. A time-series regression analysis was used to estimate trend and seasonal components in the same way as the vehicle traffic analyses of the previous chapter. Results of the regressions are given in Tables V-1 and V-2. Table V-1 shows the "goodness of fit" as indicated by the coefficients of multiple determination (R^2) and estimates of the trend line intercept and slope. Table V-2 shows the indices of monthly variation above or below the trend.

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*Since late November 1975, BART has operated approximately 18 hours per day (from 6:00 a.m. to 12:00 midnight); but only the period between 6:00 a.m. and 8:00 p.m. is considered in this analysis.

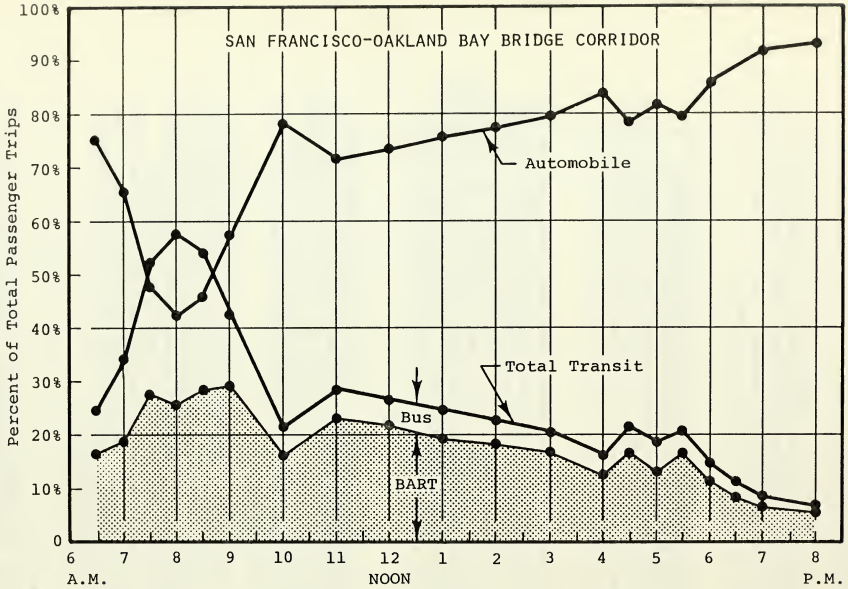

FIGURE V-1

DISTRIBUTION OF PASSENGER TRIPS BY MODE BY TIME OF DAY
WESTBOUND SAN FRANCISCO-OAKLAND BAY BRIDGE, OCTOBER 1975

Source: University of California, Institute of Transportation Studies

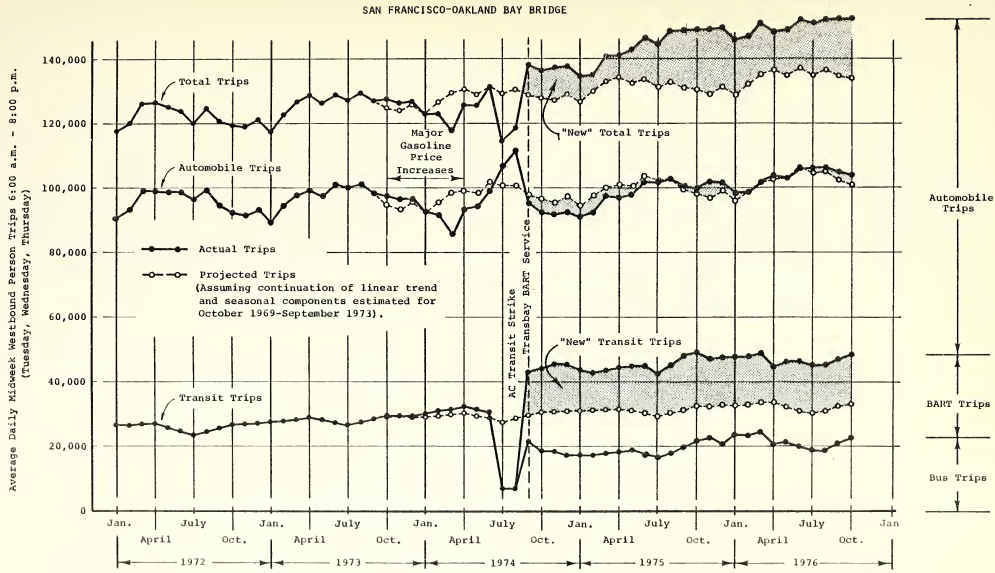

FIGURE V-2

AVERAGE DAILY MIDWEEK TRIPS BY AUTOMOBILE, BUS, AND BART IN THE SAN FRANCISCO-OAKLAND BAY BRIDGE CORRIDOR, JANUARY 1972 - OCTOBER 1976

Source: Peat, Marwick, Mitchell & Co. Analysis of Traffic and Patronage Counts Compiled by
• CALTRANS Toll Bridge Administration • University of California ITS
• BARTD • AC Transit District • Greyhound Lines.

Table V-1

TREND COMPONENT OF VARIATION IN BAY BRIDGE PASSENGER TRAFFIC
(Results of Trend-Plus-Seasonal Regressions for Period October 1969 to September 1973)

	Average Midweek Traffic (AMT), Person-Trips in One Direction, 6:00 a.m. to 8:00 p.m.					
	Trend Intercept (base level AMT, October 1969)	Trend Average (mean AMT, October 1969 to September 1973	Trend Slope (AMT increase per month)	Annual Trend (AMT increase per year	Percent Annual Trend Increase[a]	Regression Coefficient Multiple Determination (R^2)
Transit[b] (bus)	25,015	26,673	122	1,460	5.5%	0.88
Automobile	89,195	94,226	149	1,792	1.9	0.82
Total[c]	112,220	119,720	266	3,197	2.7	0.86

a. Annual trend increase as a percent of mean AMT October 1969 to September 1973.
b. Bus travel regression was based on the three-year period January 1971 to December 1973 due to lack of data before January 1971.
c. Bus travel data for October 1969 to December 1970 were estimated using the regression results of bus travel over the period January 1971 to December 1973. As a result, the total trips did not exactly equal the sum of automobile and bus trips.

Source: Peat, Marwick, Mitchell & Co. analysis of data compiled by CALTRANS Toll Bridge Administration, BARTD, AC Transit, Greyhound Lines, and University of California, Institute of Transportation Studies.

Table V-2

SEASONAL COMPONENT OF VARIATION IN BAY BRIDGE PASSENGER TRAFFIC
(Results of Trend-Plus-Seasonal Regressions for Period October 1969 to September 1973)

	Average Midweek 14-Hour Traffic (AMT) Person-Trips in One Direction 6:00 a.m. to 8:00 p.m.											
	January	February	March	April	May	June	July	August	September	October	November	December
Transit (bus)	545	726	907	1,089	- 3	-1,095	-2,186	-1,282	-380	524	558	592
Automobile	-4,573	-1,594	1,002	1,881	804	4,081	2,483	2,706	-313	-1,972	-3,130	-1,373
Total	-3,984	- 820	1,962	3,026	863	3,053	368	1,449	-612	-1,626	-2,757	- 973

Source: Peat, Marwick, Mitchell & Co. analysis of data compied by CALTRANS Toll Bridge Administration; BARTD; AC Transit; Greyhound Lines; and University of California, Institute of Transportation Studies.

Long-Term Trends. As illustrated by Figure V-2 and Table V-1, until late 1973, the number of person-trips by all modes increased steadily. For bus trips, the linear trend line shows a rate of increase of nearly 1,500 trips annually. This represents an average increase of 5.5% per year (expressed as a percentage of the average number of trips during the 14-hour day between January 1971 to December 1973).* The corresponding trend for automobile person-trips (as estimated over the four-year period October 1969 to September 1973) was an annual increase rate of about 1,800 trips or 1.9% per year. The slope of the trend line for transbay travel by all modes was an annual increase of 3,200 trips per day (2.7% per year).**

Seasonal Trends. Table V-2 summarizes variations in person-trips above and below the trend that occur as a function of the month of the year. There are two distinct patterns in the seasonal fluctuations of travel: (1) bus person-trips peak in the spring months and are at a minimum during the summer months; and (2) automobile person-trips are highest in the summer months and lowest in the winter months. Since automobile is the dominant mode of travel, the seasonal variations in total person-trips tend to follow the pattern of automobile trips.

Comparison of Actual and Projected Travel

Figure V-2 also shows projections of the "trend plus seasonal" model for total trips, automobile trips, and bus trips. As before, these projections assume that the trend and seasonal travel patterns of previous years continue unchanged, and projected volumes are taken as a baseline against which actual traffic levels are considered to have increased or decreased. The shaded areas of the figure highlight the differences between the actual and projected trip volumes.

The figure shows the effects of the gasoline crisis in early 1974; both automobile and total person-trips are well below projected levels, and bus ridership is slightly increased. The effects of the AC Transit strike in July and August of 1974 are also clear. Automobile person-trips were well above projected levels, with both transit and total person-trips drastically reduced. Only Greyhound provided significant transbay transit service in the period.

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*The regression analysis of bus trips was performed for a shorter period than for automobile trips due to a lack of pre-1971 data.

**To estimate the trend for total person-trips, 14-hour bus passenger trips for the period October 1969 to December 1970 were estimated by extrapolating the bus regression results backwards.

Changes in Automobile Trips. Figure V-2 shows that immediately after transbay BART service began, actual transbay automobile person-trips during the 14-hour day were below projected levels. However, the figure also shows that since then, actual and projected trips levels have generally differed very little, and most recently actual transbay travel by automobile has slightly exceeded projected travel. Apparently, the drop in automobile travel immediately after transbay BART has largely been offset by growth in travel for reasons other than BART.

The trend projections of automobile person-trip volumes shown in the figure may be low estimates of likely without-BART volumes insofar as the data used to estimate the regression cover a period when automobile occupancies were lower than the period covered by the projection.* Thus, the projected-minus-actual shortfall in person-trips shown in Figure V-2 is probably also a low estimate for the period of the projection (relative to the estimated shortfall in vehicles volumes shown in Figure IV-6). If the projected automobile trip volumes are adjusted to account for the change in automobile occupancy, actual automobile travel is estimated to average about 4,000 person-trips per 14-hour day less than the without-BART projection over the two years, October 1974 to September 1976. This corresponds to the estimated 3,300 vehicle-trip per 24-hour-day reduction in Bay Bridge traffic given in Table IV-3.

Changes in Transit Trips. Compared to projections of bus travel, transbay BART service increased transit ridership by over 40%. Over the two years after transbay BART opened, BART's ridership averaged 26,000 trips per day in each direction, and bus ridership averaged about 20,000 trips per day. These total 46,000 trips, compared to an average of 32,000 trips projected by the trend-plus-seasonal model of bus travel alone. The difference between the two, 14,000 trips per day, constitutes "new" transit ridership attracted at the start of transbay BART service. These "new" trips are shown as a shaded area in Figure V-2.

It is interesting to note that in the first year after transbay BART service began, BART's transbay ridership averaged about 27,000 trips per day in each direction, and transbay bus ridership averaged 18,000 trips per day for a total transit ridership of 45,000 trips per day. In the year since then, BART's transbay ridership has dropped slightly to an average of about 25,000 trips per day, while bus ridership (mainly AC Transit) has increased to 21,000 trips per day. Thus, recent increases in transbay transit ridership have all been due to increased bus ridership.

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*There is no reason to attribute this increase in automobile occupancy to BART; if anything, the reverse effect is more likely. The increase more probably results from the active promotion of car pooling on the Bay Bridge by providing toll-free car pool-only lanes.

Changes in Total Travel. Comparing actual and projected trip volumes for the two years after BART opened shows an average difference of 10,000 trips per day by automobile and transit combined (145,000 actual trips compared to 135,000 projected trips). The difference represents "new" trips, which according to the assumptions of the trend-plus-seasonal analysis, would not have been made had the opening of transbay BART (and possibly other events) not occurred.*

Modal Distribution of Transbay Travel with and without BART. Table V-3 summarizes the pattern of midweek daytime transbay travel. The average number of trips per day made by automobile, bus, and BART in the two years after transbay service began are compared with the trips that would have been made (hypothetically) if BART had not been operating. The bases for the without-BART estimates are the trend-plus-seasonal projections shown in Figure V-2 and discussed in the previous two sections.

Two further assumptions were made in constructing the table: (1) no significant diversion of travelers to bus resulted from BART's opening, and (2) no significant diversion occurred from bus to automobile.** Numbers in the table are approximate, reflecting the need to "balance" the various estimating errors involved, but in all cases are close to the corresponding actual or projected figures. The distribution of BART trips among automobile, bus, and no-trip-made is consistent with responses to the BART ridership survey questions on the previous mode of travel. (See Table II-1.)

According to the analysis summarized in Table V-3, of the average daily transbay trips made in the two years since transbay BART began, approximately 10,000 probably would not have been made had BART service not

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*The traffic projections shown in Figure V-2 are based only on the long-run trend and seasonal components of travel. To the extent that the rise in gasoline prices and the capacity of the Bay Bridge would have tended to constrain automobile travel below this trend-plus-seasonal estimate, the "projected trips" line shown in Figure V-2 should be considered a high estimate of travel volumes without BART. Accordingly, the estimate of "new" trips is low; 10,000 trips per day may be considered a "lower-bound" estimate of the number of new trips attributable to the start of transbay BART service.

**This assumption is a potential source of error since some former bus riders may have started traveling by car as a result of cutbacks in bus service following the start of BART service. This is possible especially for travelers who used Greyhound service from central Contra Costa County. Unfortunately, data are not available for estimating the extent of this diversion, if any.

Table V-3

MODE OF TRANSBAY TRAVEL WITH AND WITHOUT BART
Average Daily Midweek Westbound Person-Trips
October 1974 to September 1976
(6:00 a.m. to 8:00 p.m.)

	Mode of Travel with BART			Total Trips Projected without BART
	Automobile	Bus	BART	
Mode of Travel without BART				
Automobile	91,000	--	12,000	103,000
Bus	--	20,000	12,000	32,000
No Trip Made	8,000	--	2,000	10,000
Total Trips Actually Made with BART	99,000	20,000	26,000	145,000

Note: Reading down each of the four columns shows the estimated distribution of actual trips among automobile, bus, and "no trip made," assuming that BART is not available. For example, of the 26,000 trips actually made by BART, 12,000 would be made by automobile if BART were not available; 12,000 would be made by bus; and 2,000 would not be made at all.

Source: Peat, Marwick, Mitchell & Co.
(See accompanying text for derivation.)

started under the Bay. Of these, no more than 2,000 were made on BART itself. By implication, the remaining 8,000 "new" trips were made by automobile. These 8,000 trips correspond to between 5,000 and 6,000 vehicles, or around 6% of the total vehicles typically using the Bay Bridge between 6:00 a.m. and 8:00 p.m.

Clearly, this estimate is subject to considerable uncertainty given the many factors influencing travel volumes and associated potential estimating errors. The actual number of "new" automobile trips could be lower or higher. However, there is some basis for arguing that the 8,000-trip estimate is not unreasonably high. Since the projected 103,000 automobile trips do not account for the effects of gas price increases or Bay Bridge capacity constraints, the estimate is more likely to be high than low. If the total number of trips by all modes remains fixed, the estimate of "no trip made" is likely to be low rather than high.

Conclusions

Sources of New Transbay Automobile Trips. Available data do not permit a definitive explanation of the sources of these 8,000 apparently new automobile trips. But it seems reasonable to conclude that a large proportion of the new automobile trips on the Bay Bridge have been induced by the changes in travel conditions brought about by BART. Some portion of the new trips may have diverted from the San Mateo-Hayward Bridge, but the evidence given in Chapter IV suggests that this diversion has been small. Therefore, most of the new trips probably would not have been made across the Bay Bridge (or would have been made less frequently) without BART. These may be entirely new trips or trips previously made between locations on one side of the Bay.

As shown in Table V-3, about 12,000 transbay person-trips by automobile have diverted to BART (the equivalent of about 8,000 vehicle-trips). Apparently, about 8,000 automobile person-trips have been induced (the equivalent of about 5,000 vehicle-trips). Taken together, these numbers imply a net decrease of about 4,000 automobile person-trips (about 3,000 vehicle-trips) between 6:00 a.m. and 8:00 p.m. This result is consistent with the results of the analyses of Bay Bridge vehicle traffic volumes summarized in Table IV-3.

BART Traffic Impacts Relative to Other Sources of Variation. The net reduction of about 3,000 vehicles per day estimated in the previous section is attributable to the combined influences of BART and other factors, including the rise in gasoline prices. As illustrated in Tables IV-5 to IV-7, the regression analyses show increased gasoline prices as significant in explaining reduced traffic volumes on the Bay Bridge and other bridges studied. But the regression analyses do not show BART as a significant

explanatory factor. Therefore, a large part of the 3,000-vehicle reduction should probably be attributed to increased gasoline prices. But even if the effect of gasoline price is discounted, and all the reduction is attributed to BART (clearly a generous assumption), BART's effect is small when viewed in the context of other factors influencing traffic levels. As discussed in Chapter IV, Bay Bridge vehicle traffic has been increasing at an average annual rate of nearly 2,000 vehicles per day for several years. Typically, average daily traffic may be as much as 4,000 vehicles per day above or below the annual mean at different times of the year due to seasonal variations. Variation among days of the week is also such that there is often a difference of over 10,000 daily trips between the highest weekday and the lowest weekday.

In the context of these sources of variation in traffic volumes, a net reduction in traffic of around 3,000 vehicles per day is significant, statistically speaking, but nevertheless small in relation to the total volume of transbay travel. The reduction in automobile travel attributable to BART represents about one or two years historical growth in Bay Bridge travel and is of the same order as normal week-to-week variations in traffic.

Finally, the net traffic-reducing impacts of BART are small when viewed in the context of expectations. Early planning reports predicted that BART would remove large vehicle volumes from the Bay Bridge. For example, it was predicted that, even at current ridership levels, BART's traffic-reducing effects would be the equivalent of adding perhaps three lanes of capacity to the bridge.in the peak hour/peak direction. The above analysis shows that no such dramatic reduction in traffic volume has taken place.

Travel through the Caldecott Tunnel

Figure V-3 plots average daily westbound person-trips at the Caldecott Tunnel between the hours of 6:00 a.m. and 8:00 p.m. Included in these data are trips by persons in private automobiles, BART, and Greyhound buses.

Since traffic volumes in April and October are close to the mean, seasonal variations are not evident in the graph. However, long-term trends are apparent, with total person-trips increasing steadily over the period shown. The trend line for automobile trips followed closely that of total person-trips until the spring of 1973 when automobile trips decreased significantly probably due to the opening of BART's Concord Line. A further reduction occurred in late 1973 and early 1974 as a result of gasoline shortages and price increases. Early in the summer of 1974 when gasoline became more available, automobile trips again resumed an increasing trend (which was apparently unaffected by the start of transbay BART

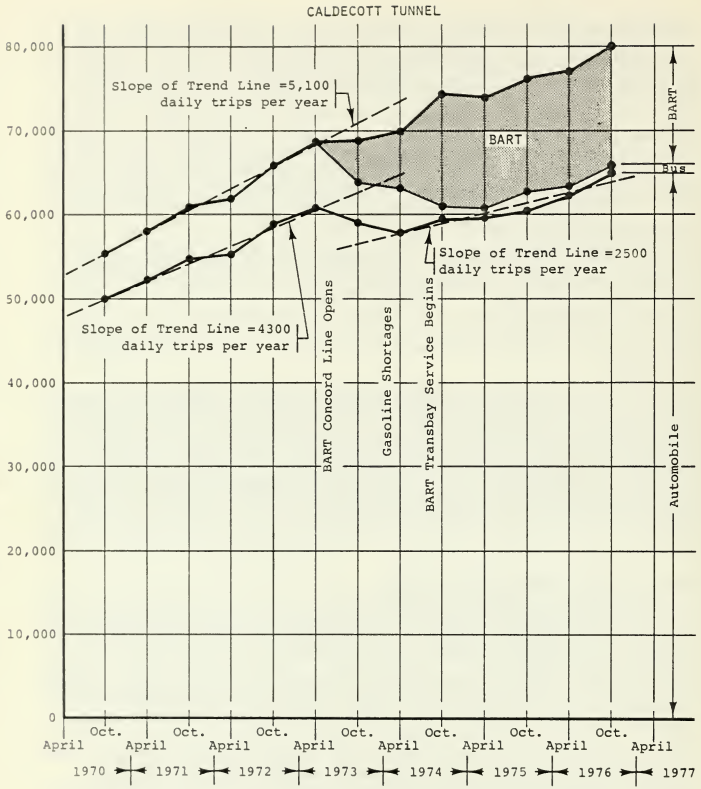

FIGURE V-3

CALDECOTT TUNNEL TOTAL TRAVEL VOLUME
OCTOBER 1970 - OCTOBER 1976

Source: Peat, Marwick, Mitchell & Co. Analysis of Data Collected by University of California, Institute of Transportation Studies.

service). But due perhaps to the presence of transbay BART and the residual effect of higher gasoline prices, the rate of increase appears to be slower than before.*

Travel by bus was quite stable from October 1970 to April 1973. Since then, bus ridership has fallen following the opening of BART's Concord Line and the start of transbay BART service. However, this reduction has clearly been compensated for by travel on BART.

Changes in Automobile Trips. Extrapolation of the pre-BART automobile trip trend line shown in Figure V-3 suggests that had other factors remained unchanged, 14-hour westbound automobile travel in April 1974 would have been approximately 64,500 person-trips, 6,900 more than the actual level of 57,600 person-trips. This may be considered the reduction caused by the gasoline shortage and price effect as well as the start of BART Concord Line service and represents a shift in the growth of automobile trips of about one to two years.

Changes in Total Trips. Interestingly, BART ridership on the Concord Line in April 1974 was also 6,900 trips--suggesting that the increase in BART ridership was equal to the decrease in automobile trips

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*However, the difference in the rates of growth are not statistically significant. Two regression runs were performed for automobile person-trips through the Caldecott Tunnel. The first run was performed for the period between October 1970 and April 1973 (a total of six observations). The trend model was determined to be

$$y = 47,615 + 2,150t$$

where

y is the volume of 14-hour westbound automobile person-trips, and t is elapsed time in six-month units

An equivalent regression was performed for the period April 1974 to October 1976 (a total of six observations), and the estimated model was:

$$y = 56,076 + 1,242t$$

A comparison of the slopes of these two regression lines indicates that the rates of growth are not significantly different at the 5% level of significance.

caused by BART and all other factors. The analyses of the previous chapter suggest that the gasoline shortages and price increases probably had a significant traffic-reducing effect in the Caldecott Tunnel corridor. This, in turn, suggests the appearance of "new" automobile trips which, for the same reasons as were hypothesized for the Bay Bridge, may have been "induced" in the heavily-traveled Caldecott Tunnel corridor by the reductions in traffic congestion caused by diversion of automobile travel to BART. The large increase in total trips following the start of transbay BART service may indicate the appearance of further induced trips by BART and automobile. However, as with the earlier analysis of Bay Bridge corridor travel, the data do not support any definite conclusions.

VI. CHANGES IN HIGHWAY TRAFFIC CONGESTION

The previous two chapters discuss the diversion of travel to BART and the impact of this diversion on travel volumes by automobile. Accompanying these changes in travel volumes have been changes in the service provided by the highway system, i.e., changes in highway traffic congestion and travel times.

Distribution of Bay Bridge Traffic over the Day

Figure VI-1 plots the distribution of Bay Bridge traffic over a 24-hour day for April 1974 (after the gasoline crisis but before BART transbay service), April 1975 (after BART transbay service began), and April 1976.

Confirming the data in Figure IV-6, Figure VI-1 shows that the 24-hour traffic volume was the same in April 1975 as in April 1974; and that the distribution of traffic over the day in April 1975 was practically the same as in April 1974, except during the morning peak hours and between 10 p.m. to 11 p.m. The figure also shows that in April 1976, traffic volumes were higher than in the previous two years, both in total and at most hours of the day.

Figure VI-2 focuses on morning peak-period hourly vehicle flows on the Bay Bridge in April 1974, 1975, and 1976, and shows traffic volumes between the hours of 6:00 a.m. and 10:00 a.m. Table VI-1 summarizes a statistical comparison of peak-period hourly traffic volumes occurring in each of the three years. It also compares totals for the 14 hours, 6:00 a.m. to 8:00 p.m., and 24-hour totals.*

The analysis of Table VI-1 suggests that significantly more vehicles passed through the Bay Bridge between 7:00 a.m. and 8:00 a.m. in April 1975 compared to April 1974, suggesting some "sharpening" of the peak. However, total vehicle flow during the 4-hour period 6:00 a.m. to 10:00 a.m. was the same in both April 1974 and April 1975. Similarly, total 14-hour and 24-hour volumes are not significantly different for April 1974 and April 1975. The analysis of Table VI-1 also shows that traffic volumes in April 1976 were significantly higher for almost all periods shown compared with 1974 and 1975. Thus, what small reductions in peak-period traffic volumes may have been effected by BART were more than offset by April 1976.

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*The data shown are the average of vehicle totals abstracted from the Toll Bridge Administration's Bay Bridge totalizer records for the midweek days (generally Tuesdays and Wednesdays) shown in Table IV-1 for each month.

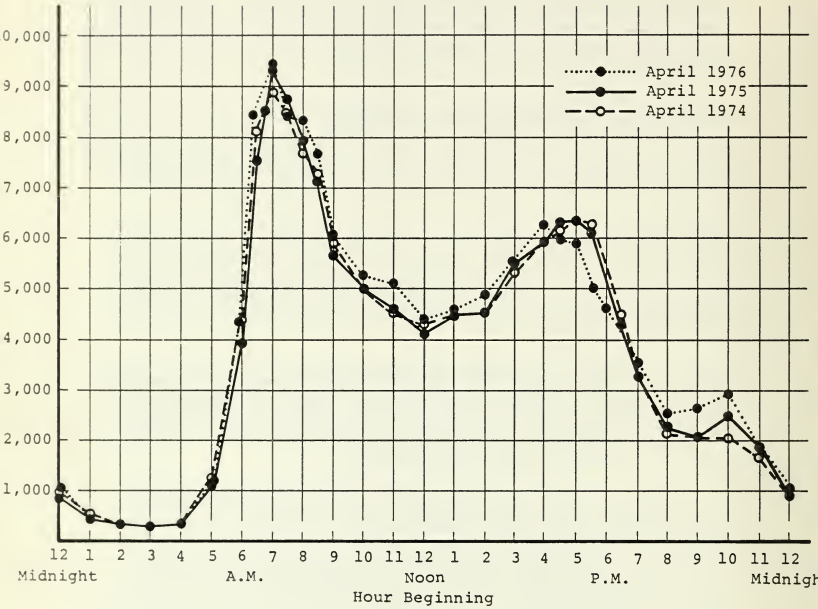

FIGURE VI-1

SAN FRANCISCO-OAKLAND BAY BRIDGE WESTBOUND VEHICLE TRAFFIC
TYPICAL MIDWEEK DISTRIBUTION OF TRAFFIC OVER THE DAY,
APRIL 1974, 1975 AND 1976

Source: University of California ITS, Surveys of Bridge Traffic

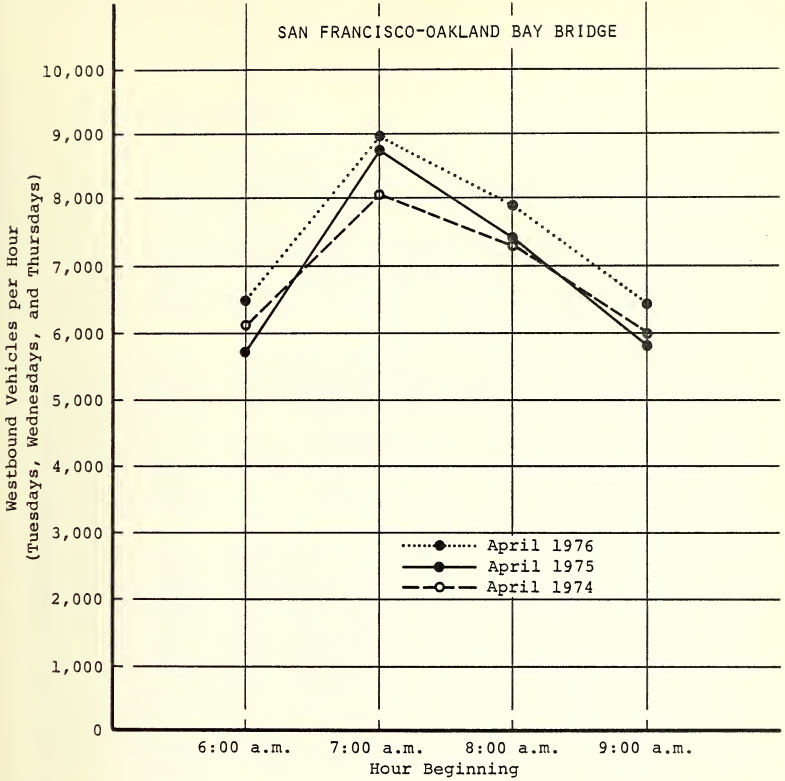

FIGURE VI-2

SAN FRANCISCO-OAKLAND BAY BRIDGE WESTBOUND VEHICLE TRAFFIC
AVERAGE MIDWEEK PEAK PERIOD DISTRIBUTION
APRIL 1974, 1975 AND 1976

Source: Peat, Marwick, Mitchell & Co. Analysis of Data
Compiled by CALTRANS Toll Bridge Administration

Table VI-1

SUMMARY OF STATISTICAL ANALYSIS OF BAY BRIDGE MORNING PEAK-PERIOD TRAFFIC VOLUMES

Test Hypothesis[a]	Statistic[b]	Time of Day: 6:00 a.m. -7:00 a.m.	7:00 a.m. -8:00 a.m.	8:00 a.m. -9:00 a.m.	9:00 a.m. -10:00 a.m.	14 hours 6:00 a.m. -8:00 p.m.	24 hours
--	$\bar{X}_{74}$	6,046	8,029	7,261	5,964	76,417	87,794
--	n_{74}	8	7	8	8	7	7
--	$\bar{X}_{75}$	5,618	8,729	7,389	5,754	76,799	89,568
--	n_{75}	8	8	8	8	8	8
--	$\bar{X}_{76}$	6,495	8,908	7,890	6,394	81,705	96,507
--	n_{76}	9	9	9	9	9	9
H_o: $\bar{X}_{74} = \bar{X}_{75}$	t	5.53	4.06	0.78	2.27	0.47	1.58
H_1: $\bar{X}_{74} < \bar{X}_{75}$	$t_{.95,f}$[c]	--	1.77	1.76	--	1.77	1.77
H_1: $\bar{X}_{74} > \bar{X}_{75}$	$t_{.95,f}$[c]	1.76	--	--	1.76	--	--
Reject/Cannot Reject H_o		Reject	Reject	Cannot Reject	Reject	Cannot Reject	Cannot Reject
H_o: $\bar{X}_{75} = \bar{X}_{76}$	t	8.96	0.78	2.72	3.44	9.54	8.20
H_1: $\bar{X}_{75} < \bar{X}_{76}$	$t_{.95,f}$[c]	1.75	1.75	1.75	1.75	1.75	1.75
Reject/Cannot Reject H_o		Reject	Cannot Reject	Reject	Reject	Reject	Reject

a. H_o is the null hypothesis, and H_1 is the alternative hypothesis.

b. $\bar{X}_i$ and n_i are mean hourly vehicle volume and sample size, respectively, for sample i. And i = 74, 75, 76 represents a sample of April 1974, April 1975, and April 1976 data, respectively.

c. $t_{.95,f}$ represents the 0.95 point of the t-distribution with f degrees of freedom. If the value of the test statistic t is greater than $t_{.95,f}$, the null hypothesis is rejected at the 5% level of significance.

Source: PMM&Co. analysis of data compiled by CALTRANS Toll Bridge Administration.

Bay Bridge Metering System

Among the few data which allow some conclusions to be drawn on how BART has influenced traffic congestion are the records of the metering system used to control traffic flows on the Bay Bridge. Since March 14, 1974, a system of metering westbound traffic entering the five lanes of the San Francisco-Oakland Bay Bridge has been operational. The flow of traffic leaving the 17 toll-booth lanes is controlled by a red or green traffic light above each lane* before the pavement merges into five lanes at the beginning of the bridge structure itself. The traffic lights are operated automatically by detectors which monitor the rate of flow of vehicles entering the bridge. At normal flow rates, all lanes show a green light.

The metering system is activated (and shows periodic red lights above lanes) when traffic flow-rate density increases above a specified level, indicating reduced speeds and a buildup of congestion on the bridge. Thus, the starting time and duration of metering-system operation are interesting measures of congestion on the Bay Bridge for which data are available on a continuing and consistent basis. Figures VI-3 and VI-4 show the times of system activation during the morning peak period for Tuesdays, Wednesdays, and Thursdays, day-by-day from March 1974 until August 1976. Gaps in the figure indicate days for which data are not available.

Figures VI-3 and VI-4 indicate a fairly consistent pattern of traffic congestion from March to June 1974, with day-to-day variations about the norm caused by weather, traffic accidents, and other influences. The starting time, duration, and day-to-day variations in the duration of metering all increased dramatically in July and August of 1974 giving a clear picture of the traffic congestion caused by the AC Transit strike in those two months. The period of activation then decreased in September when transbay BART service began. But since then, the period appears to have increased back to higher levels. By late 1975, it had increased to a level close to that of early 1974; and by early 1976, the period of activation was considerably higher than two years earlier. This is illustrated more clearly by Figures VI-5 and VI-6, showing the metering-system start time, and by Figures VI-7 and VI-8, showing the duration of flow control.

Comparing the 11-week period (mid-March to end of May) in 1974 following the start of metering-system operation with the corresponding period in 1975 (about six months after transbay BART started) shows that the period over which the metering system operated starts later (7:09 a.m. on average in 1975 compared to 6:59 a.m. in 1974) and has a shorter duration (80 minutes in 1975 compared to 91 minutes in 1974). Both these differences are statistically significant at the 5% level.

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*There are actually 15 traffic lights since the 17 lanes merge to 15 lanes just before the lights.

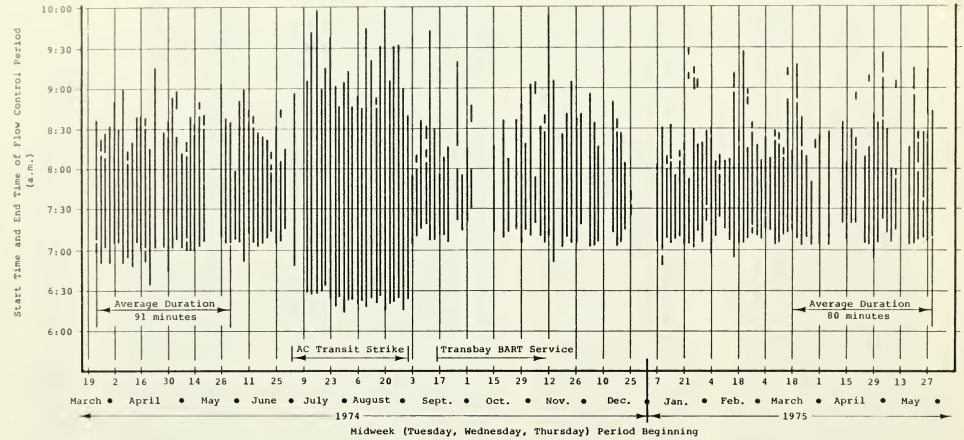


FIGURE VI-3

TIMES OF ACTIVATION OF THE SAN FRANCISCO-OAKLAND BAY BRIDGE TRAFFIC METERING SYSTEM
TUESDAYS, WEDNESDAYS, AND THURSDAYS, MARCH 1974 - MAY 1975

Source: CALTRANS Toll Bridge Administration, Daily Records of Bay Bridge Metering System.

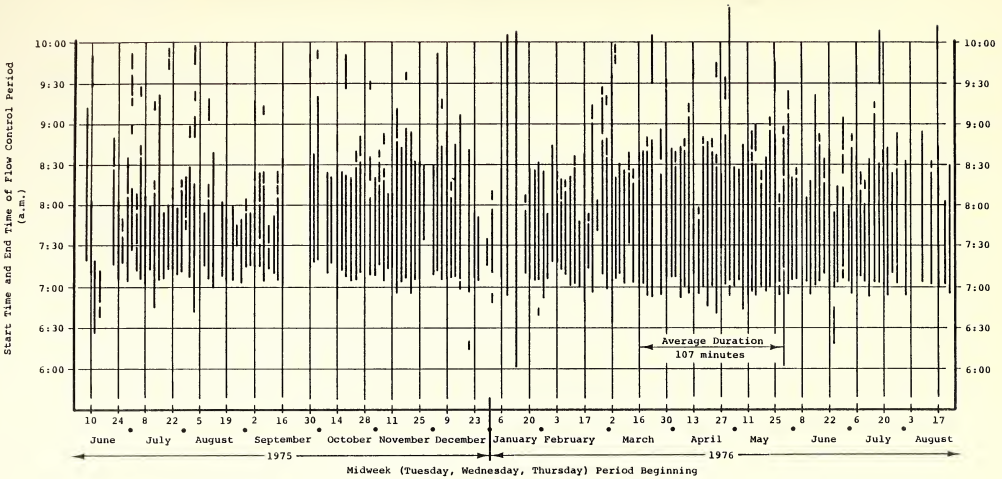


FIGURE VI-4

TIMES OF ACTIVATION OF THE SAN FRANCISCO-OAKLAND BAY BRIDGE TRAFFIC METERING SYSTEM

TUESDAYS, WEDNESDAYS, AND THURSDAYS, JUNE 1975 - AUGUST 1976

Source: CALTRANS Toll Bridge Administration, Daily Records of Bay Bridge Metering System.

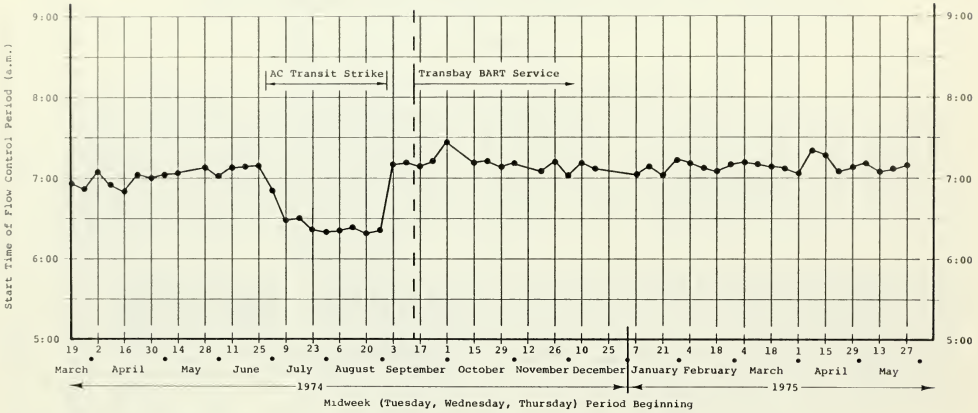


FIGURE VI-5

START TIME OF ACTIVATION OF THE SAN FRANCISCO-OAKLAND BAY BRIDGE TRAFFIC METERING SYSTEM
TUESDAYS, WEDNESDAYS, AND THURSDAYS, MARCH 1974 - MAY 1975

Source: CALTRANS Toll Bridge Administration, Daily Records of Bay Bridge Metering System.

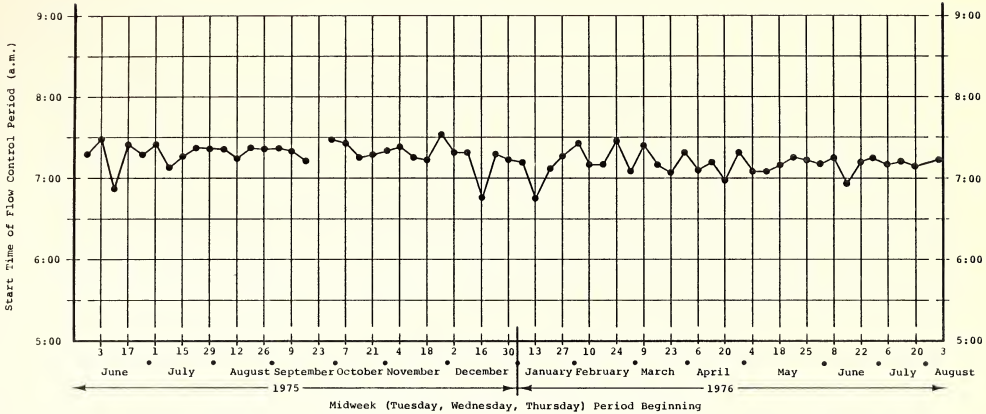


FIGURE VI-6

START TIME OF ACTIVATION OF THE SAN FRANCISCO-OAKLAND BAY BRIDGE TRAFFIC METERING SYSTEM
TUESDAYS, WEDNESDAYS, AND THURSDAYS, JUNE 1975 - AUGUST 1976

Source: CALTRANS Toll Bridge Administration, Daily Records of Bay Bridge Metering System.

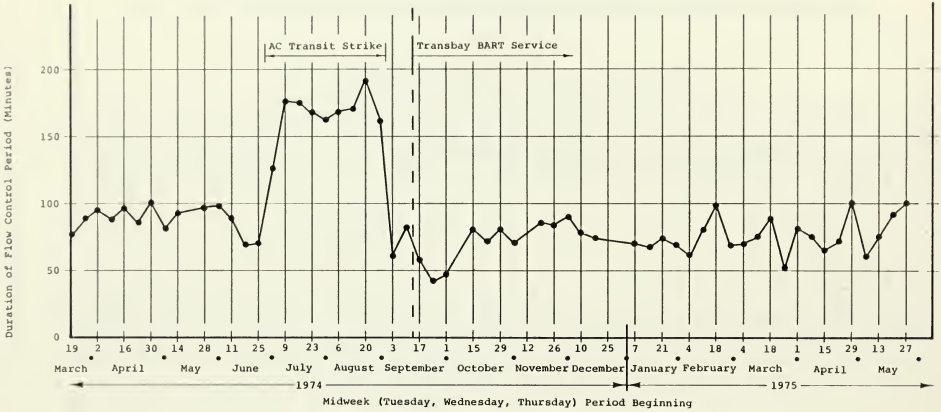


FIGURE VI-7

DURATION OF ACTIVATION OF THE SAN FRANCISCO-OAKLAND BAY BRIDGE TRAFFIC METERING SYSTEM
TUESDAYS, WEDNESDAYS, AND THURSDAYS, MARCH 1974 - MAY 1975

Source: CALTRANS Toll Bridge Administration, Daily Records of Bay Bridge Metering System

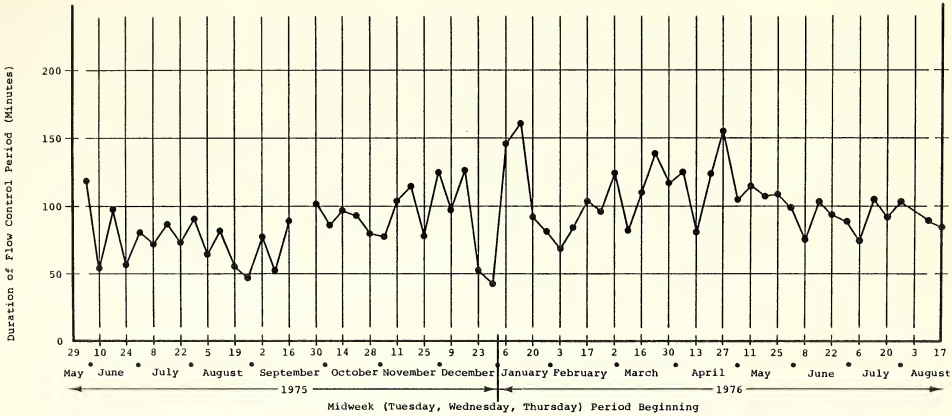


FIGURE VI-8

DURATION OF ACTIVATION OF THE SAN FRANCISCO-OAKLAND BAY BRIDGE TRAFFIC METERING SYSTEM
TUESDAYS, WEDNESDAYS, AND THURSDAYS, JUNE 1975 - AUGUST 1976

Source: CALTRANS Toll Bridge Administration, Daily Records of Bay Bridge Metering System

Looking at the corresponding (mid-March to end of May) period in 1976, the average start time was 7:02 a.m., and the average duration of flow control had increased to 107 minutes. Statistical tests show that the start times in 1974 and 1976 are not significantly different; however, the durations of flow control are quite different--the period in 1976 being significantly longer than in 1974 or 1975. Table VI-2 summarizes the statistical comparisons.

Comparison of Highway Travel Times

Highway travel-time surveys are the traditional method of measuring changes in traffic congestion. A considerable body of travel-time data for various times before and after the start of service on BART lines has been collected and analyzed as part of the TSTB Project. Unfortunately, many factors have influenced traffic patterns over the period of BART's introduction making it hard to attribute changes to BART, especially when surveys of "before" and "after" situations are far apart. These factors include the 55-mph speed limit introduced in January 1974, and several new traffic control measures (such as the metering system) on the Bay Bridge (see Table I-1). The generally small sample sizes of travel-time observations available for a given section of highway at any one time also make analysis difficult. (Typically, the number of data points obtained in the TSTB Project surveys for each section is not more than three or four.) Occasionally, the data were unreliable because of traffic accidents or other "unusual events." Because of the small sample sizes, normal day-to-day fluctuations as well as variations in traffic congestion due to weather conditions and accidents influence the analysis of traffic congestion changes greatly. Other surveys were performed in different months of the year, thereby introducing seasonal variations in the data collected.

For these reasons, it is difficult to assess the impacts of BART on congestion levels from the travel-time survey results. However, bearing in mind the weaknesses in the data, whenever it is possible to draw conclusions, analyses of the data point to the same general conclusions suggested in the discussion of the Bay Bridge metering system: (1) reductions in peak-period travel times have occurred, but these have been small relative to total travel times; and (2) the most congested periods appear to have shifted to slightly later times of the day.

Changes in Bay Bridge Peak-Period Travel Times. Figure VI-9 summarizes the results of two morning peak-period travel-time surveys conducted over the Bay Bridge. The first (pre-BART) survey was conducted in April 1974 and the second (post-BART) survey in May 1975. Transbay BART service started in September 1974.

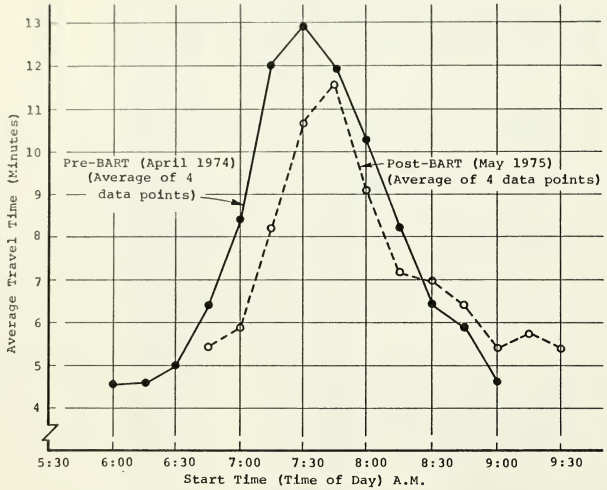
Table VI-2

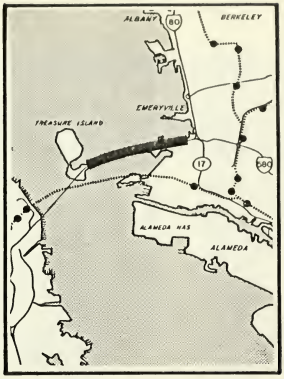
SUMMARY OF STATISTICAL ANALYSIS OF BAY BRIDGE METERING SYSTEM

	Start Time of Metering System (a.m.)				Duration of Flow Control (minutes)			
	1974 vs 1975		1974 vs 1976		1974 vs 1975		1974 vs 1976	
	1974	1975	1974	1976	1974	1975	1974	1976
Mean $\bar{X}_i$	6:59	7:09	6:59	7:02	91	80	91	107
Sample Size n_i	26	25	26	31	26	25	26	30
Null Hypothesis	$\bar{X}_{74} = \bar{X}_{75}$		$\bar{X}_{74} = \bar{X}_{76}$		$\bar{X}_{74} = \bar{X}_{75}$		$\bar{X}_{74} = \bar{X}_{76}$	
Alternative Hypothesis	$\bar{X}_{74} < \bar{X}_{75}$[a]		$\bar{X}_{74} < \bar{X}_{76}$[a]		$\bar{X}_{74} > \bar{X}_{75}$		$\bar{X}_{74} < \bar{X}_{76}$	
test-statistic	4.51		1.14		2.13		3.01	
$t_{.95,f}$	1.68		1.67		1.68		1.68	
Reject/Cannot Reject H_o	Reject		Cannot Reject		Reject		Reject	

a. The alternative hypothesis of $\bar{X}_1 < \bar{X}_2$ for testing the difference in mean start time is the same as an alternative stating that the mean start time for sample 1 is earlier than that for sample 2.

Source: PMM&Co. analysis of data recorded by CALTRANS Toll Bridge Administration.





Event between Pre-BART and Post-BART Data:

- BART transbay service began September 1974

FIGURE VI-9

MORNING PEAK PERIOD (WESTBOUND) TRAVEL TIMES ON SAN FRANCISCO-OAKLAND BAY BRIDGE
WEST GRAND AVENUE (OAKLAND) TO TREASURE ISLAND: 3.2 MILES

Source: CALTRANS and BART Impact Program, Moving Car Observer Travel Time Surveys.

The relatively short period between the "before" and "after" data sets and the fact that they were collected at about the same time of the year means that the differences between the two graphs in Figure VI-9 may be attributed to BART with some confidence. However, the effects of the gasoline crisis complicate the picture. In April 1974, traffic levels were depressed because of gasoline shortages in February and March and accompanying price increases.

Figure VI-9 shows that peak-period travel times in May 1975 were about 1.5 minutes shorter than in April 1974. This represents an increase in overall average speed from about 16 mph to 18 mph at the most congested time. The most congested part of the peak period has shortened and shifted to a slightly later time; the figure shows a shift of about 15 minutes (from 7:30 a.m. to 7:45 a.m.).

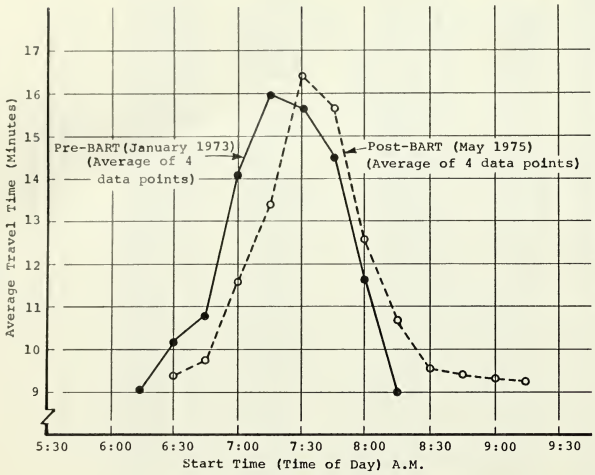
Changes in Route 24 Peak-Period Travel Times. Figure VI-10 shows a summary of morning peak-period westbound travel times on Route 24 before and after BART service began on the Concord Line and transbay. As shown in the figure, the section of Route 24 surveyed parallels the BART Concord Line from Lafayette to Oakland and is a major connector to the Bay Bridge.

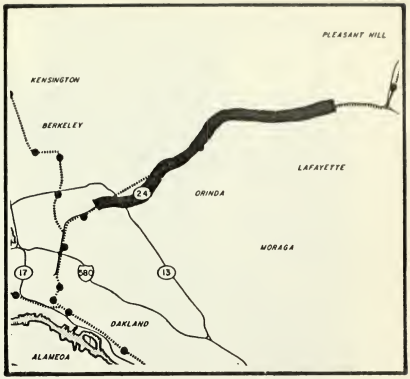
The figure shows no change in the travel time between the two surveys at the most congested time of day. But the peak has shifted to slightly later in the day--by about 15 minutes--with accompanying reductions in travel times early in the peak period. This is consistent with the conclusions for the Bay Bridge.

Again, a number of events--in particular the gasoline crisis--influenced traffic patterns over the period involved, and purely seasonal variations may account for some of the differences between the January and May observations. Because of these influences on traffic patterns, the changes in peak-period travel times in Figure VI-10 cannot be attributed to BART with any confidence.

Changes in Route 17 Peak-Period Travel Times. Figure VI-11 shows a summary of morning peak-period (northbound) travel times on Route 17 before and after BART service began on the Fremont Line and transbay. The section of Route 17 studied parallels the BART Fremont Line from the San Leandro to Lake Merritt Stations.

The figure shows the travel times in the two surveys are practically the same. This is because of the absence of congestion on this section of Route 17 both pre-BART and post-BART. (Figure IV-11 shows that average travel times on this section of freeway were between 5.5 and 6.5 minutes, representing average speeds of 50 to 60 mph.)





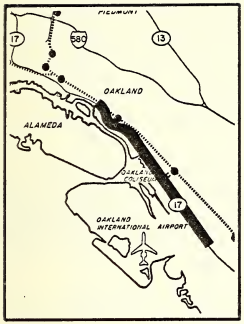
Events between Pre-BART and Post-BART Data:

- BART Concord Line opened May 1973
- Gasoline shortages and price increases occurred winter 1973-1974
- 55 mph speed limit introduced January 1974
- BART transbay service began September 1974

FIGURE VI-10

MORNING PEAK PERIOD (WESTBOUND) TRAVEL TIMES ON ROUTE 24
OAKHILL ROAD (LAFAYETTE) TO BROADWAY (OAKLAND): 6.1 MILES

Source: CALTRANS and BART Impact Program, Moving Car Observer Travel Time Surveys.



Events between Pre-BART and Post-BART Data:

- BART Fremont Line opened September 1972
- Gasoline shortages and price increases occurred winter 1973-1974
- 55 mph speed limit introduced January 1974
- BART transbay service began September 1974

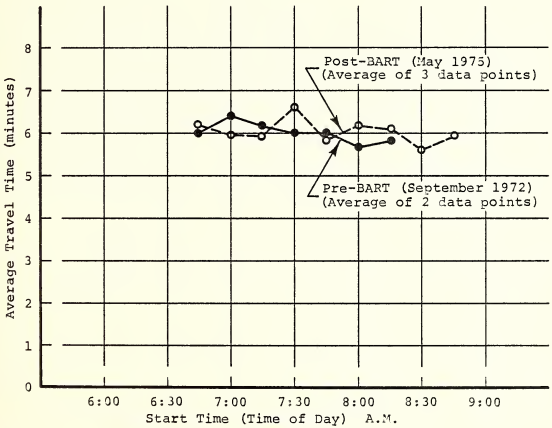


FIGURE VI-11

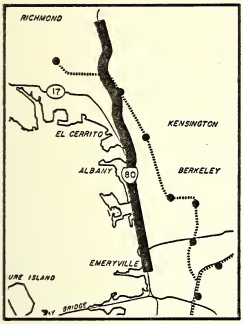
MORNING PEAK PERIOD (NORTHBOUND) TRAVEL TIME ON ROUTE 17
98TH AVENUE (OAKLAND) TO 5TH AVENUE (OAKLAND): 5.6 MILES

Source: CALTRANS and BART Impact Program, Moving Car Observer Travel Time Surveys.

Changes in Route 80 Peak-Period Travel Times. Figure VI-12 shows afternoon peak-period (northbound) travel times on Route 80 before and after BART service began on the Richmond Line and transbay. The section of Route 80 surveyed parallels the Richmond Line from the Ashby Station in Berkeley to Richmond. The figure suggests that travel times were about the same at the time of the two surveys, although it appears that "post-BART" traffic may have "spread" over a longer period--the effect being to reduce the length of the period with high delays and increase the period of moderate delays.

Once again, several factors influenced traffic patterns over the relatively long period between the surveys. These include the gasoline crisis and the introduction of the 55 mph speed limit, the small sample sizes, and possible seasonal variation in traffic between November and May. Because of these influences, it is not possible to conclude whether or not BART has affected traffic congestion on this section of Route 80.

Conclusions. Although a considerable amount of travel-time survey data are available for various locations and various times before and after the start of service on BART lines, the preceding analyses illustrate that the data allow few conclusions to be drawn about BART's impacts on highway traffic congestion. This is for the reasons listed earlier--the principal weakness being the smallness of the sample size available for any given comparison. Among the freeways paralleling BART a conclusion can only be drawn for the San Francisco-Oakland Bay Bridge. This conclusion is consistent with the travel patterns analysis of the previous chapters: reductions in peak-period travel times occurred on the Bay Bridge after BART service started, but they were small compared to total travel time. The available evidence does not indicate a measurable BART-related reduction in traffic congestion on any other Bay Area highways.



Events between Pre-BART and Post-BART Data:

- BART Richmond Line opened January 1973
- Gasoline shortages and price increases occurred winter 1973-1974
- 55 mph speed limit introduced January 1974
- BART transbay service began September 1974

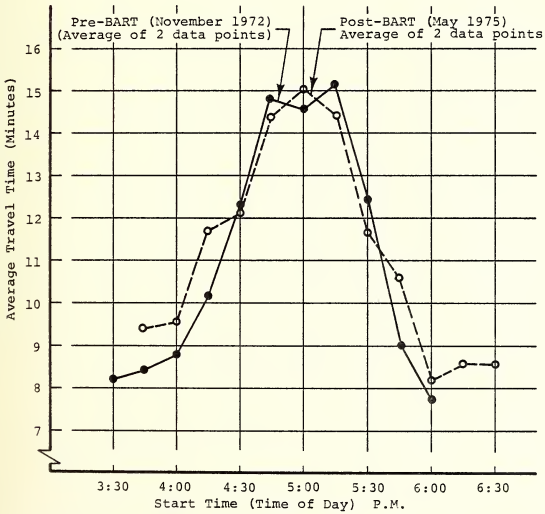


FIGURE VI-12

AFTERNOON PEAK PERIOD (NORTHBOUND) TRAVEL TIMES ON ROUTE 80
POWELL STREET (EMERYVILLE) TO SOLANO AVENUE (RICHMOND): 7.6 MILES

Source: CALTRANS and BART Impact Program, Moving Car Observer Travel Time Surveys.